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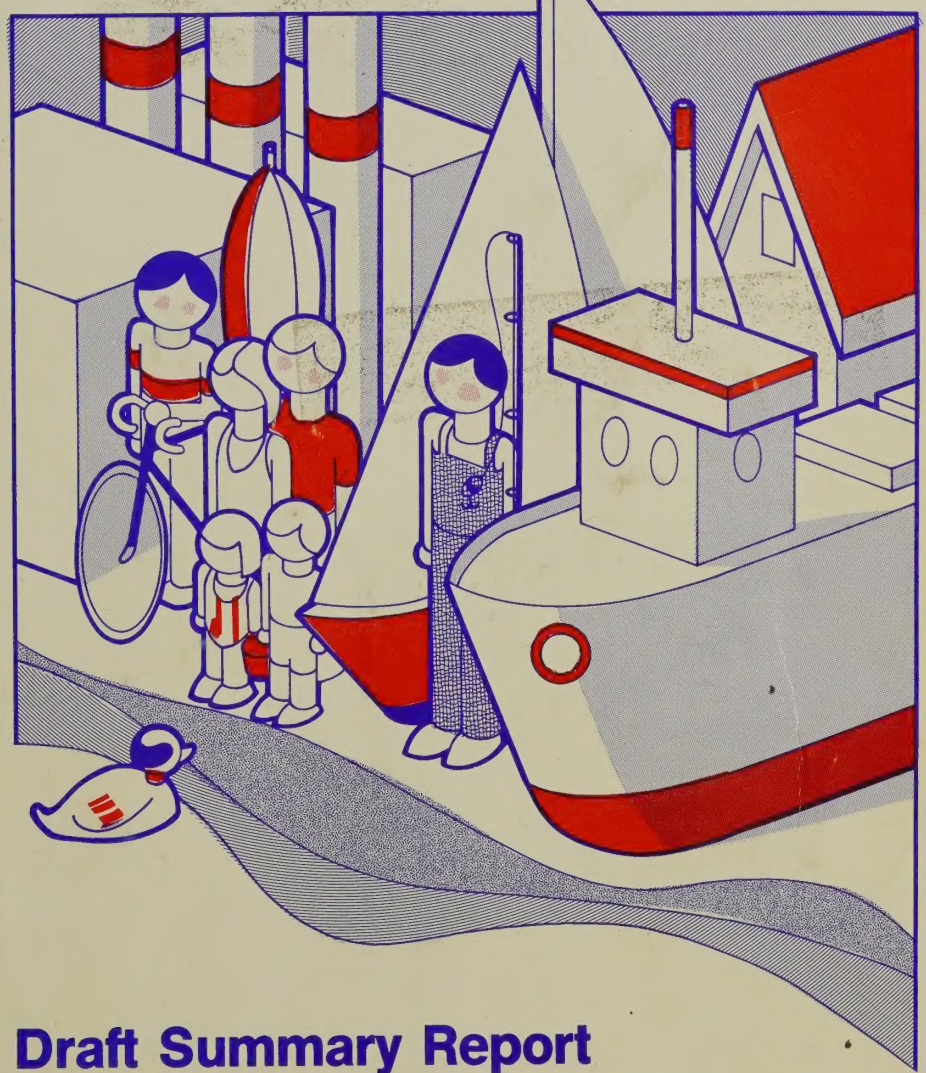
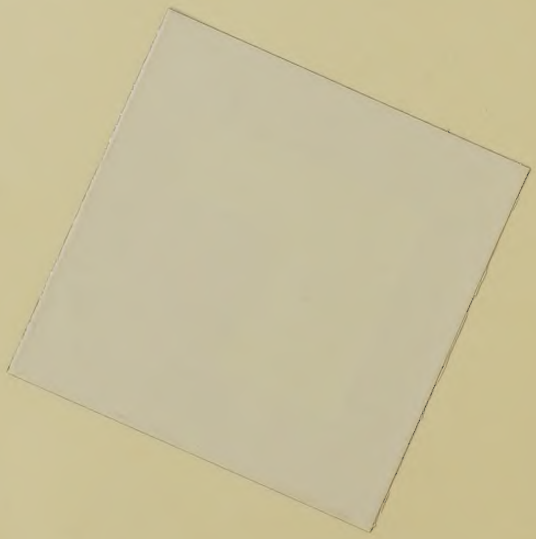
Remedial Action Plan for Hamilton Harbour



Draft Summary Report

March, 1987



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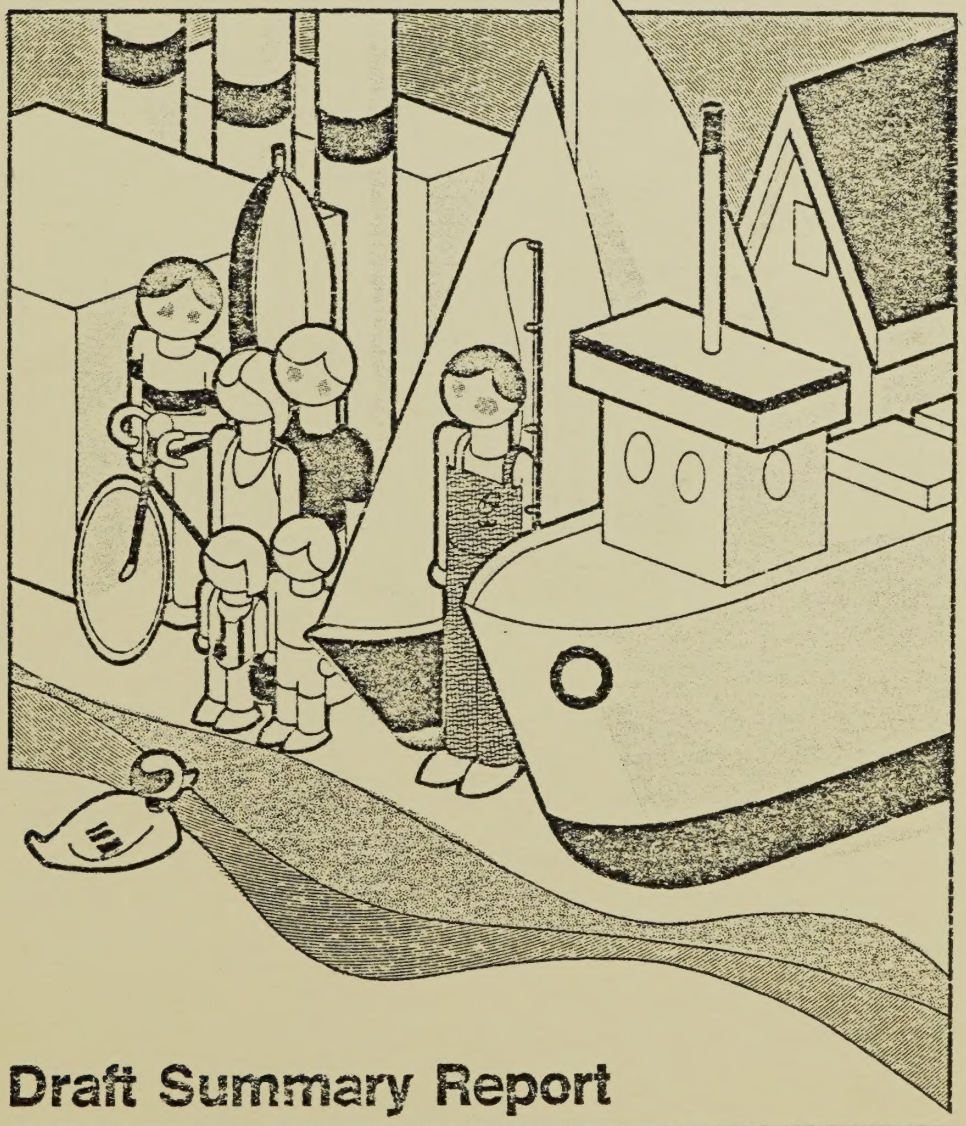

Draft Summary Report

March, 1987

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GOVERNMENT DOCUMENTS

INTERIM REPORT

of the

WRITING TEAM

for the

HAMILTON HARBOUR
REMEDIAL ACTION PLAN

"Towards a Comprehensive Remedial Action Plan
for Hamilton Harbour"

by

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1.0 THE REASONS FOR DESIGNATING HAMILTON HARBOUR AS AN "AREA OF CONCERN"

The Great Lakes Water Quality Board, the principal advisor to the International Joint Commission (IJC) on Great Lakes water quality issues, has identified 42 Areas of Concern in the Great Lakes Basin (see figure 1). Despite considerable progress over the past decade, serious problems remain in certain areas where IJC or jurisdictional standards are exceeded and additional remedial measures are necessary to restore beneficial uses.

Hamilton Harbour has been designated as an Areas of Concern. In their report of 1985, the Water Quality Board outlined their reasons for so designating Hamilton Harbour. Their summary is reproduced in Exhibit I. It is this set of problems that the Remedial Action Plan must address.

Underlying this assessment of the Harbour by the Board there are assumptions about the use of the Harbour. The Water Quality Board decided that, in order to provide an ecological perspective, they would consider environmental quality data for sediment and biota as well as for water itself. They have also decided to evaluate these areas with uniform criteria. Behind these criteria lies the basic philosophy that they are attempting to protect the waters for the most sensitive use.

Theoretically, if a decision is made to forego the most sensitive use, the criteria could change. In the past, decisions were not made on what uses would or would not be supported. The view was held, and rightly so, that a broader concensus was required on the part of the public that was being affected most directly. To achieve a measure of that concern is one purpose of the public consultation process.

In addressing the issues shown in Exhibit 1, the Remedial Action Plan does have to consider the broader impact of the situation on all residents of the Lake Ontario basin. But in many aspects the critical concern will be a question of improvements for the local benefit which are largely independent of any concerns for people or bodies of water outside those close to the local communities.

2.0 OVERVIEW OF THE ACTION PLAN

2.1 Introduction

The fact that a formal process of developing an Action Plan has just recently been initiated (June, 1986) does not imply that nothing has been done in the past to control pollution in the Harbour. The two sewage treatment plants discharging effluent into the harbour are already meeting the requirements under the Great Lakes Water Quality Agreement. The major industries discharging to the harbour will soon be meeting all the requirements of the current Ontario Ministry control orders.

Public consultation is an important element of the process and serves a variety of purposes. It is needed for refinement of the goals for water quality improvements. It should, as well, provide a forum for discussion of cross-jurisdictional issues and develop heightened awareness of the overall program. The Writing Team is engaged in a continuing discussion of the issues that arise in the preparation of the Plan.

Finally, the plan must include the design of a monitoring system to ensure that the Action Plan and the results expected are proceeding on schedule.

Several recent publications have been used extensively by the Writing Team. They are listed at the back of this report. These reports have provided an excellent background on the environmental conditions. Recommendations of the Hamilton Harbour Technical Summary (1985) for additional research has led to work on organic contaminants, fisheries and re-aeration technology (amongst others). Some of these studies have not reached the stage of published reports, but the Writing Team has had access to these investigators and their work in developing an approach to the Action Plan. Several fact sheets, and presentations to the Stakeholders have been made by members of the Writing Team and need not be duplicated here.

Our knowledge of the Harbour and of Cootes Paradise is in a state of flux. Considerable advances are being made that have a direct bearing on remedial plans. Much of the new information coming forward is targetted specifically on questions raised in the development of an Action Plan.

The Writing Team has also been helped extensively by other staff of the organizations represented on the team. Their assistance is greatfully acknowledged.

The Writing Team will have completed a detailed description of the physical, chemical and biological situation in the Harbour and Cootes Paradise by April, 1987.

3.0 PUBLIC CONSULTATION

3.1 The Two Processes

Two public consultation processes have been employed. Public meetings for the general population of the watershed are open sessions designed to provide the most recent information on the Remedial Action Plan, and to permit formal presentation of briefs from interested groups. These briefs will be considered by the Writing Team and the "Stakeholder Group".

The second process has been to establish a "Stakeholder Group" made up of agencies, organizations, institutions, government departments, industries and private citizen groups who make use of,

who wish to make use of, or in some manner have jurisdiction over the use of Harbour water. Some 60 potential stakeholders were interviewed individually, and eventually 49 have come to form the group.

Through a 2-day workshop in July, 1986, and through subsequent meetings, the Stakeholder Group has developed an Interim Report on their proposals. This report was submitted to the Ministers of the Environment for Canada and Ontario, and forms one point of reference for the Writing Team.

The development and updating of the Remedial Action Plan will be a continuing process of consultation. The Stakeholder Group has collectively expressed the wish to be a forum for review of matters having a bearing on the remedial actions proposed for the Harbour.

3.2 The Interim Report of the Stakeholder's

The Interim Report of the Stakeholders is a detailed analysis of the beneficial uses to which the Harbour is, or could be put. The Group prefaced their presentation with five approaches or principles, including the ecosystem approach, the principles of human health, public acceptance, access, and aesthetics.

The Group then proceeded to develop recommendations and general remedial actions for two groups of goals. There were specific goals and actions to permit the current defined uses, including recreational boating, water sports , shipping and navigation, industrial uses, and waste water receiving body.

They then addressed uses that could be enhanced and goals for future use where they are not presently available. These included fisheries, wildlife appreciation, swimming, and educational resource.

The reader is encouraged to consult the full report of the Stakeholders. A summary of the goals developed by the Stakeholders is given in Exhibit II.

The Writing Team is considering this very comprehensive list of beneficial uses in the light of the goals for water quality improvement.

4.0 POTENTIAL REMEDIAL PROGRAMS

4.1 Overview

In considering the nature of the problems associated with improving beneficial uses of the Harbour, there are three categories of activities that are being discussed in the light of the potential for water quality improvements. Many of these are not specific to the "Writing Team" task. The three categories include:

a. Factors affecting the image of the Harbour and efforts of the communities around the Bay to focus on collective planning,
b. Potential for actions to control or affect water quality, and
c. Physical factors requiring attention.

The items within each of these categories are listed in Exhibit III.

4.2 Overall Factors - Focus on the Harbour

Many of these factors affecting the image of harbour and the efforts to focus planning around the Harbour, have arisen in discussions with or among the stakeholders. The Writing Team would first draw attention to the existing environmental assessment and public review processes that makes any Remedial Action Plan viable. Since we are now attempting to manage this body of water as a full aquatic system, supporting diverse beneficial uses is essential that future developments in the Harbour do not undo the remedial actions.

While it is outside the bounds of the Remedial Action Plan (RAP), issues such as access to the harbour seem very important to ensure the greater benefit from improvements in water quality. The issues surrounding water quality in the harbour are not just technical matters - they are issues of how the public views and uses this resource.

In this last regard, we would recommend a quantitative approach to the question of the public perception of the Harbour in the form of a marketing and attitude survey, a current use survey, and a study of the carrying capacity of the Harbour. This can be done in concert with planning for improvements to water quality.

4.3 Potential for Action to Control Water Quality

The factors listed in the second section of Exhibit II, with two exceptions, represent primarily a focus on clearing up sources of contamination to the harbour. In these cases the control of water quality comes through our ability to collect the contaminant at the source, or to collect it at the point of treatment before it enters the harbour waters. Care must be taken to ensure that the waste problem is not simply transferred to the land or air.

One option is to redirect a discharge so that it impacts directly on Lake Ontario, rather than impacting on both the Harbour and the Lake. This option will be discussed in more detail below.

The potential for artificial oxygenation of the bottom waters of the Harbour in summer represents a direct attack on the problem of reduced oxygen levels by artificially adding oxygen. This technique may be required to supplement ammonia and nutrient controls. The ammonia and nutrient loadings to the Harbour are at the root of the problem of low dissolved oxygen in the deeper waters in summer.

All of these approaches are included in Exhibit III.

The water quality situation and the related control programs are addressed in greater detail in the next major section of this report. Before attending to the details of the water quality program, however, there is a third category of control or regulatory activity that should be addressed in order to provide a comprehensive view of the activities that must be initiated or maintained to realize some of the benefits of improved water quality.

4.4 Physical Factors Requiring Attention

Outside of water quality and sediment quality improvements, probably the largest factor that will have to be considered in order to realize the goal of an enhanced wildlife community and an enhanced self-sustaining warm water fishery, will be the provision of more suitable aquatic habitat. Habitat of a type necessary for the nesting of birds, for food, for fish spawning, for fish fry survival and for escape from predators, are all deemed to be limiting for fish and wildlife in the Harbour and in Cootes Paradise. Key factors include the abundance and distribution of submerged and emergent vegetation, the need for suitable bottom materials (e.g., sand and gravel, as opposed to mud), the need for shallower water depths to replace those already lost in shoreline development, as well as development of islands or new irregular shorelines with embayments and points of land attractive to fish. Plans for the location of new shores or islands will need to be keyed to locations where water quality improvements may reasonably be expected to benefit the fish or the development of weed beds.

The question of the effect of movements of large vessels in stirring contaminated sediments is thought to be of minor concern in contrast with other issues.

Infilling of the Harbour, on the other hand, is an issue that parallels the concern for habitat development. There seems to be potential here to seek some mutually beneficial approach to developmental infilling and habitat improvement.

5.0 STRATEGIES TO DEAL WITH WATER AND SEDIMENT QUALITY, AND WITH BIOTA IN HAMILTON HARBOUR AND COOTES PARADISE

5.1 Introduction

The factors limiting each use of the harbour are tabulated in Exhibit IV. Aside from the obvious conflict of uses, it can be seen that turbidity and nutrients affect all uses, and that the

bacteria and toxics have collectively the greatest direct impact on human health through contact with water, or through the consumption of fish.

Many of these factors are interrelated in the ecology of the Harbour, presenting a somewhat complex task. Figure 2 illustrates the principal links.

The concentration of materials in water or sediment for which the IJC or MOE have standards are the items circled. The organisms receiving benefit from the program are shown in rectangular boxes.

Not only are there interactions within the Harbour, the possible remedial actions (Exhibit III) can, individually, affect more than one of these factors. For example, the strategy of minimizing the flow of raw sewage to the harbour while allowing for the maximum treatment of urban stormwater runoff reduces loadings of bacteria, suspended solids (turbidity) and phosphorus to the Harbour in one systematic approach. Where possible we would wish to take full advantage of such multiple benefits.

5.2 The Key Problems

We immediately face two major technical problems associated with water and sediment quality. The first of these is tied into ammonia treatment and phosphorus control at the Burlington and Hamilton Sewage Treatment Plants (STP's). The second major concern is the historically contaminated sediments that are distributed widely over the deeper water of the main Harbour. This is not to say that the other problems are not large, but that our approach to these first two questions will determine, in large measure, how the other water quality issues may be tackled.

In regard to habitat improvements, some progress can be made independently of the water quality issues, especially in Cootes Paradise.

5.3 Ammonia and Phosphorus

The proposals for addressing ammonia and phosphorus relate to the low oxygen conditions in the bottom waters of the Harbour in summer, and to the clarity of water. As illustrated in Figure 2, treatment of ammonia will have a direct effect on the problem of low oxygen. Ammonia in the harbour water is estimated to give rise to about one-half of the low oxygen condition. A potential, but unproven, benefit from ammonia treatment may be avoidance of some toxic effects of ammonia when it is discharged under ice where it cannot be readily oxidized. In the main Harbour, the Hamilton STP is the major source of ammonia. Ammonia treatment, if carried out with adequate final filtering, should have no deleterious side effects.

The impact of phosphorus removal on dissolved oxygen conditions is indirect. It is mediated through the phytoplankton biomass. The biomass utilizes the phosphorus as a nutrient. Through a part of its life cycle, and through decomposition after the plant material dies, the biomass creates a demand on the oxygen in the harbour water. The phytoplankton biomass is also a major component of turbidity in the main harbour in summer.

The problem with control of the phytoplankton biomass through phosphorus control is that there is presently an overabundance of phosphorus for the existing levels of biomass production. This means that it is likely that phosphorus loadings to the harbour would have to be reduced by 70% or more to cause even a 50% reduction in biomass production (a 50% reduction of phosphorus loading may only result in a 10% reduction in average summer biomass). A 70% reduction in phosphorus loading through heroic treatment measures at the STP's, a 50% reduction of phosphorus in all streams (an optimistic assessment of the real potential), and an elimination of all the combined sewer overflows to the harbour - all of these measures could <u>just</u> reach the 70% reduction that appears to be needed. And then there is no buffer for future expansion of the population.

Another option is to divert both the Hamilton and Burlington STP's to the open lake. In this way we would achieve the level of reduced phosphorus loading for all time, obviate the need for extraordinary phosphorus and ammonia treatment, but face the question of how to ensure that the outfalls would have no impact on the beaches and nearby water intakes.

Some measure of the scale of impact on the lake as a whole can be estimated. The phosphorus and ammonia loadings to Lake Ontario would be no more than what is being asked of other major cities like Toronto or Rochester because the Burlington and Hamilton STP effluents currently meet the same treatment standards as all other plants. In fact, however, it would double the current loading to Lake Ontario from the Burlington and Hamilton STP's because one-half of the current loadings remain in the Harbour, and hence only one-half of these loadings reach the lake through the ship canal. In essence, we are taking abvantage of the ability of the harbour to treat effluents before they exit to Lake Ontario.

The diversion option should be studied immediately. We need an analysis of how such effluents would affect the drinking water of Hamilton and Burlington. Although the Stakeholders have rejected the diversion concept on principle, it is a viable option.

If it is not feasible to divert STP effluent to Lake Ontario there may be severe constraints on what can be achieved in regard to phytoplankton biomass control (and consequently for turbidity or water clarity in summer) within the Harbour. The fact is that the harbour, because it is such a small body of water, is far less able to accommodate the phosphorus loadings than Lake Ontario.

The utility of pursuing additional phosphorus control for discharges into the harbour needs further exploration. It is possible that such controls will reduce peak blooms of phytoplankton even if it doesn't change the overall production level. This then addresses some potential periodic nuisance problems, but probably wouldn't have any significant effect on the problem of low dissolved oxygen or of water clarity.

The problem of low dissolved oxygen should, however, be addressed in its own right. Improvement in oxygen levels improves fish habitat by providing a more acceptable cool-water refuge when shore and surface water temperatures are high in summer. It also could have a beneficial effect on the contaminants in the bottom sediments. A plentiful supply of oxygen near the sediment-water interface may help keep the contaminants in the sediment more tightly bound in the sediment and hence less available to the aquatic ecosystem.

For this reason, <u>if</u> diversion to Lake Ontario is ruled out, we would recommend immediate attention to treatment of ammonia discharges wherever it is economically feasible. This program could also be supplemented by a program of direct oxygenation of bottom waters in summer. A feasibility study planned for improved ammonia treatment at the Hamilton STP. A feasibility test has already been carried out on direct oxygenation of the bottom waters in summer. The report for the STP is due April, 1988, and a pilot scale study of a direct oxygenation technique in the harbour is scheduled for the coming summer. The relative costs and benefits (or advantages) of these two approaches to solving the low oxygen condition could be completed by the end of 1987.

5.4 Water Clarity

A portion of the water clarity problem is caused by suspended material carried to the harbour or Cootes Paradise in streams, by wave-induced resuspension of bottom sediments in the shallower waters, and by carp activity. Efforts to control these factors in Cootes Paradise should be pursued, as it is probably limiting the extent of marsh vegetation in that area, through interference with light penetration into the water and through burial of submerged plants.

The reason we raise the issue of turbidity at this point in the discussion is because we recommend that control measures for suspended material must be coordinated with nutrient controls for the Harbour. As mentioned above, there is an excess of nutrient available for biomass production. This production at a lower level than potential has been reported to be due to suspended material reducing light penetration. Consequently any major reduction in the loading of suspended material (turbidity) into the harbour might generate larger biomass production with its attendant deleterious consequences.

To summarize the ammonia/phosphorus/water clarity issues:

(a) A thorough investigation of the impact of waste disposal in the Lake must be carried out.

(b) If the diversion strategy is rejected on technical grounds, we are left with two considerations:

(i) can the dissolved oxygen problem be tackled by a combination of ammonia treatment and artificial oxygenation? and

(ii) to what degree can phosphorus loading controls contribute to a reduction of oxygen demand that causes the low dissolved oxygen, or contribute to an improvement in water clarity?

To address these questions we need a measure of the feasibility of ammonia control at the STP's, a pilot study of the direct oxygenation technique (see Appendix 2), and a further analysis of the existing data on phosphorus, phosphorus loading, water clarity and phytoplankton biomass in the Harbour. This last analysis is essential because phosphorus treatment technology can be costly, and the loadings have to be reduced very substantially to achieve a measureable impact on the Harbour.

(c) Phosphorus control and ammonia treatment should be pursued for reduction of loadings to Cootes Paradise. The Paradise is shallow and has a short residence time. The improvement in critical parts of the area should be immediate and beneficial.

(d) Reduction in suspended material loadings to the Harbour will be useful, but care will have to be taken to keep this remedial program in step with nutrient controls. Scientists have indicated that improvements in water clarity could give rise to greater algal blooms with the existing nutrient levels in the Harbour. Reduction of suspended loadings to Cootes Paradise will have an immediate and beneficial effect.

5.5 Toxic Contaminants

Two categories of toxic contaminants are listed in Figure 2 - heavy metals and persistent organic chemicals. There is a third category of contaminants, the so-called "conventional" toxic substances, that includes phenols, cyanide, chlorine and ammonia. Ammonia has been addressed above in another context. The remainder of the third category have been dealt with in terms of current loadings to the point where harbour waters now meet water quality objectives. While these must be watched in the monitoring program, the predominant problem is the historical deposits of contaminants still present in the sediments of Windermere Basin and in the sediments of the main harbour.

Windermere Basin has been the subject of separate study by several agencies. Concern has been expressed about the contaminated sediments, and about the aesthetic problem associated with the area. There is also concern for the contaminants being transferred into the waterfowl population that uses the Basin in summer and winter. It should be noted that, in large measure, this waterfowl habitat is artificial. Birds winter there because of the heat from the sewage treatment plant, and the basin is confined and shallow because of harbour infilling and accumulation of waste sludge.

Finally, we have to consider the widespread toxic contaminant problem in the central and SE basins of the Harbour. The sediments have contaminant contents that exceed the guidelines for open-lake disposal of dredged material. Dredge spoil is placed in confined artificial ponds on the east side of the SE basin. The capacity of existing disposal ponds will be reached by the year 2000. If confined disposal is required after 2000, then consideration should be given to utilizing it in such a way as to enhance the development of a useful littoral zone (assuming that it is the chosen method of disposal). The Harbour Commission has no plans yet to deal with contaminated dredge spoil after the year 2000.

There is evidence that the contaminants in the sediment in deeper water are gradually being buried by cleaner sediments and perhaps more isolated from the aquatic ecosystem. On the other hand there is evidence that bottom fauna are taking up some of the contaminants, and hence there is a possibility that the contaminants can be introduced into the food chain in the local environment. This is true for bottom fauna such as chironimids in deeper waters, and for waterfowl that feed on the bottom in shallower waters.

Dredging the whole open harbour and removing the sediment seems impractical. Techniques for in-situ treatment or manipulation of the sediment in the harbour (extraction, treatment at the surface, and replacement) are being developed or tested in other harbours. But there has been no study of currently available technology to achieve some measure of remediation. This should be reviewed for feasibility.

Parallel with the study of potential remedial techniques, some studies should be carried out which are specific to the Hamilton Harbour situation. Studies are required which will establish the stability of the contaminants in the sediment, or will elucidate how they may be locked into the sediment. With the present evidence, it is difficult to make a clear case that the contaminants in the deeper waters of the harbour are causing problems.

5.6 Combined Sewer Overflows

There is a general policy in the Province that there shall be no discharge of raw sewage into any watercourse. A large part of Hamilton has a system of combined storm and sanitary sewers.

During heavy rain storms, the combined sewers overflow and raw sewage will then bypass the STP and enter the Harbour directly. The advantage of the combined sewer system is that some of the stormwater or normal street runoff does get treated in the STP.

One solution that has been implemented in some cities is to separate the sanitary and storm sewers. This prevents the loss of raw sewage to the water course, but provides no treatment at all for storm water. Storm water generally carries bacteria, toxic contaminants, suspended solids and phosphorous.

There is a middle course between having sanitary sewer overflows and completely untreated storm runoff. New technology developed at McMaster University has shown that development of storage facilities at key locations in the city could allow operation of control structures within a combined sewer system to prevent sanitary sewage overflow in a storm, permit collection of the first surge of stormwater (which is usually the most contaminated) and allow spillover of only the less contaminated final stormwater. A computer control system and storm sensing network are required to allow this system to operate effectively. The Hamilton-Wentworth Region has applied to MOE for trial of such a system for part of the city of Hamilton. If successful, considerable benefit to water quality in the Harbour would result, (see Appendix I). In the meantime, combined sewer overflow (CSO) is being addressed in the Redhill Creek area. Our recommendation would be to target Chedoke Creek for CSO remediation in the next stage of this work, followed by remediation for drainage into the west end of the harbour. These are both preferred areas for certain sensitive beneficial uses.

6.0 OTHER POTENTIAL REMEDIAL ACTIONS

6.1 Carp Control

For the development of marsh in Cootes Paradise and in the west end of the Harbour, plans should be made to harvest carp, or to develop techniques to exclude carp from areas where marsh development would be desirable.

6.2 Leachate Control

Current information confirms the view that leachate control from landfill sites is either controlled or it represents a very minor part of the problem in Hamilton Harbour.

6.3 Bacteria

Attention to the CSO's on the south shore of the Harbour, and the effluents of the Burlington and Hamilton STP's will deal with a large component of the bacterial contamination of the Harbour. This will improve the situation generally for body contact sports and recreational boating. For swimming, the Stakeholders have suggested that the west end and the north shore should be the focus

our efforts to reinstate suitable conditions. We lack information on bacterial contamination along the north shore. Experience in other areas suggests that storm runoff gives rise to high bacteria counts as well as stagnation during warm periods in summer, especially when combined with bather density, can also give rise elevated bacteria counts.

Existing information and new data, especially for the north shore, must be analyzed to establish whether bacteria concentrations can, in fact, be controlled to the extent that users would not be continually faced with temporary beach closures.

6.4 Heat

Industrial and municipal effluents are discharged with added heat. There has been some indication that warm waters in the Harbour may adversely affect the fish population. On the other hand, the warm effluents from the Hamilton STP probably serves to keep the Windermere Basin sufficiently open to attract the duck population that now winters in that area.

Thermal structure in the harbour is a determining factor in the development of low oxygen conditions. The low oxygen is found in the deeper, colder layer of the Harbour in summer. That same colder water can be a refuge for fish from elevated nearshore or surface temperatures. Since thermal structure development in the Harbour is a function of the weather and the exchange of water between Lake Ontario and the Harbour, its variation from year to year can affect dissolved oxygen conditions.

To summarize, warm temperatures are not considered a major concern at this time. Some exploration of this issue is warranted, however, and the matter should be clarified in the coming year.

6.5 The Municipal - Industry Strategy for Abatement (MISA)

While both municipal and major industrial effluents are either meeting existing standards (or will shortly do so), the municipal, and iron and steel sectors will come under review in the MISA program. Under present plans the iron and steel industry are scheduled to be subject to monitoring regulations by April, 1988, with effluent limits to be established in March, 1989. Municipal effluents in this region will be subject to new monitoring regulations in September, 1988, with effluent limits being set by December, 1989. The first set of MISA regulations will relate to the best available technology that is economically achievable. The constraints for the receiving waters are, as we have suggested in earlier sections, more severe than current standards.

7.0 REVIEW OF USES IN THE LIGHT OF THE POSSIBLE REMEDIAL ACTIONS

7.1 Wildlife Habitat

Re-establishment of marsh areas is necessary for habitat improvement. Improvement of water clarity by reducing algal growth and sediment load from erosion will aid expansion of marsh areas. Other factors believed to be affecting the re-establishment of marsh areas, especially in Cootes Paradise, include water levels, the disturbance of bottom sediments by wave action, and the activities of carp. Areas can be dyked off to permit the control of water levels, sedimentation, and access to carp. The impact of such structures on desirable fish species must be considered for any such development.

7.2 Boating and Other Water Sport

The improvements already outlined will also make Hamilton Harbour more suitable for boating and other water sports. The control of combined sewer overflows, treatment of storm water where necessary, and improved removal efficiencies for suspended solids at the municipal sewage treatment plants will reduce the coliform counts in the harbour. Improved removal of suspended solids at municipal sewage treatment plants, control of combined sewer overflows, and improved stream erosion control will reduce phosphorus inputs, and thus reduce algal growth, resulting in greater water clarity. This, along with landscaping, will make the harbour more aesthetically pleasing for boating and other water sports.

7.3 Swimming

To make the harbour suitable for swimming it is necessary to control the source of pathogenic bacteria. These sources include combined sewer overflows, sewage treatment plant effluents, and storm sewer discharges.

The Regional Municipality of Hamilton-Wentworth has initiated a program for providing containment of sewage during times of precipitation to minimize combined sewer overflows. This program is described under the program for controlling ammonia discharges (Appendix 1).

Municipal sewage treatment plant effluents remain a source of coliform bacteria even though chlorination is being practiced to disinfect the effluent. Chlorine must directly contact the bacteria to destroy them. Suspended solids in the effluent reduce the effectiveness of chlorination as bacteria within the particles are protected from direct contact with chlorine. Filtration of the sewage treatment plant effluent, to reduce phosphorus inputs will also reduce suspended solids concentrations, and therefore increase the effectiveness of disinfection.

Storm sewer discharges can contribute to coliform counts. Further monitoring is needed to determine where storm water may be affecting water quality and where treatment of storm water may be necessary.

7.4 Aesthetics

Completion of the water pollution control measures as outlined under rehabilitation of the fishery will also improve the aesthetics of the harbour water.

The clean-up options for Windermere Basin have been reviewed. Isolating portions of the basin by constructing dykes and then placing contaminated sediment into these dyked areas would appear to be the optimal method of clean-up.

7.5 Fishery

The restoration of a fishery is one of the most demanding of the goals or beneficial uses for the harbour (see Exhibit IV). Major issues include the continuing loss of submerged and emergent plants, increased turbidity, contaminated sediments, loss of littoral habitat, reduced dissolved oxygen, eutrophication and an unstable thermocline. Fisheries habitat in Hamilton Harbour and Cootes Paradise have deteriorated to the point that conservation alone will not meet the long term goals. Habitat restoration activities, such as removing or capping contaminated sediments and suspended sediment control, are needed to deal with the issues of contaminated sediments and increased turbidity. In other areas, extensive habitat development is needed to replace lost marshes and littoral zones.

There is guarded optimism that a more extensive and better balanced warmwater fishery may be restored to the Harbour. And while a self-sustaining cold water fishery is unlikely to be established, improvements may allow for better access of these fish to the harbour and less adverse conditions for them to cope with.

Generally speaking, the improvements noted above for other uses will take some of the stress off the existing fish populations and improvement may be seen as a result of such remediation. But more than this is required, such as:

- identification of factors implicated in fish tumours/lesions
- increased marsh areas
- more diverse benthic community
- reduced water temperatures
- development of new physical habitat to replace that already lost, and
- top predator introductions.

A full remedial plan for a fishery would be a product of the studies under way in the Department of Fisheries and Oceans.

8.0 SURVEILLANCE

Hamilton Harbour pollution sources have undergone improvement over the past decade. There is an opportunity to examine the record of conditions and how they have changed as a result of both the nutrient and toxic chemical controls that have been put into place.

To examine the conditions during 1987 and compare those with previous years will also give us the opportunity to better gauge the impact of any additional measures that may be required for the future.

The design of an efficient and economical monitoring system for the future contains some substantial challenges. The literature indicates that conditions within the Harbour are variable or "patchy" in nature. In addition, the flushing of the harbour by exchange of water between the Harbour and the lake through the ship canal has been cited as a major factor in keeping the Harbour water in better condition. Since that flushing action is largely subject to wind conditions, to rainfall and to the warmth of the seasons, means will be found to interpret the conditions in the light of these natural conditions that are not under our control.

For this reason we recommend that a substantial effort be made to solve these questions within the next year, so that we have the means to adequately monitor the progress of the water quality remedial programs.

9.0 SUMMARY AND CONCLUSIONS

In this report we have outlined the various methods by which contaminants may be controlled in Hamilton Harbour. The analysis has gone beyond the Harbour to consider the upstream area of Cootes Paradise, and to consider Lake Ontario, the receiver of effluent from Hamilton Harbour.

The remedial plans that affect the sewage treatment plant effluents for nutrients, bacteria, ammonia and suspended solids will be established after the impact of phosphorus control on the Harbour is properly quantified, and the feasibility of diverting the effluents is clearly established. Such remedial measures for the sewage treatment plants, linked with the changes planned for the combined sewer overflows could bring water quality into compliance for total phosphorus and phytoplankton biomass. It will also reduce bacterial levels and improve the low dissolved oxygen condition - although not to levels entirely suited to the water quality objectives for swimming or fish habitat.

Bacterial levels will probably require stormwater treatment in addition to improved STP treatment in order to bring them into strict compliance with the needs for swimming.

Low oxygen conditions may still give rise to the need for artifical reoxygenation in Hamilton Harbour at the most critical times of the year, even if loadings from the sewage treatment plants are virtually eliminated. Alternatively, a combination of ammonia treatment and repeated reoxygenation may be feasible to restore oxygen levels to the standard.

Control of suspended solids loading to the Harbour is required, but must be carefully phased so as not to aggravate phytoplankton blooms.

Controls on inputs of phosphorus, suspended solids and ammonia to Cootes Paradise will all have an immediate and beneficial impact on that body of water.

Removal of contaminated sediments in Windermere Basin is recommended under careful environmental monitoring.

Assessment of the role of contaminants in the sediments as they affect uses of the harbour in the main body of the Harbour is essential. No recommendation for removal or treatment is being made at this time. Potential treatment strategies should be explored in concert with the agencies dealing with the other 38 Areas of Concern in the Great Lakes where similar types of problems exist.

Habitat improvements will have to parallel water quality measures if the full potential for fish and wildlife goals are to be achieved.

Results to be Expected in FY 87/88

1. Completion of ammonia control study for the Hamilton STP.
2. Completion of CSO remediation for the Redhill Creek area ($5 million).
3. Completion of phenolics control at STELCO.
4. Feasibility study of dyking for Cootes Paradise (Royal Botanical Gardens).
5. Completion of pilot demonstration for artificial oxygenation of the summer hypolimmion (Environment Canada).
6. Re-establish baseline data for water quality of Harbour to gauge impact of past remedial measures and set the basis for future surveillance (DOE, MOE).
7. Design of the future surveillance program (MOE).
8. Final assessment of contaminants in the Harbour sediments for characterization of their likely environmental impact.
9. Feasibility of a diversion strategy to be established in terms of siting, impact and economics.
10. Define degree of phosphorous control required for Harbour and establish whether it is achievable.
11. Development of a Fisheries Rehabilitation Plan.
12. Completion of a pre-dredging study for Windermere Basin.
13. Define sources of phosphorus and suspended solids in streams and measures that may be taken to abate them.

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Hamilton Harbour Technical Summary and General Management Options, Ontario Ministry of the Environment, August 1985.

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Hamilton Harbour Trace Contaminants of 1982-83: Loadings to, and Concentrations in the Harbour, Ontario Ministry of the Environment, June, 1986.

Municipal - Industrial Strategy for Abatement (White Paper), Ontario Ministry of the Environment, June 1986.

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EXHIBIT I

HAMILTON HARBOUR (Ontario)

NATURE OF PROBLEM

June 1985

Types of Problems

Conventional Pollutants
Heavy Metals
Toxic Organics in Fish
Contaminated Sediments
Eutrophication
Fish Consumption Advisories
Aesthetics

Sources of the Problems

Municipal Point Sources
Industrial Point Sources
Urban Nonpoint
Combined Sewer Overflows
In-Place Pollutants

Municipal and industrial discharges, urban drainage, sediments, and algal decay increase oxygen demand. This oxygen demand depresses hypolimnetic dissolved oxygen levels, especially in the summer. This, in turn, limits the suitability of the deeper part of the harbour as a fish habitat.

Aesthetic quality is diminished by poor water clarity and colour, as a result of high levels of suspended solids, chlorophyll, and dissolved organics, thereby detering broader recreational use of the harbour.

Significant levels of nutrients, several heavy metals, and PCB in the surface sediments from several portions of Hamilton Harbour. The problem is severe in Windermere Basin. Dredged material is disposed in confined areas.

Objectives are exceeded for total dissolved solids, zinc, ammonia, and phosphorus. Iron, cyanide, and phenolics also exceed the objectives on occasion, especially adjacent to the steel mills on the south shore.

Levels of trace organic (PCB, PAH), phenols in fish under investigation.

PROGRESS TO DATE

Remedial Actions

Sewage treatment in place-operational improvements undertaken; further municipal changes may be required.

Industrial discharges of phenol is partial compliance and further control measures under consideration.

Dredging and alternatives to confined disposal of contaminated sediment disposal under investigation with specific project to be undertaken in Windermere basin.

Further remedial measures to address phenol, nutrients, and dissolved oxygen. Feasibility of remedial action under investigation.

Regular effluent and ambient monitoring.

Environmental Improvements

Major reductions of municipal and industrial pollutant loads including conventional pollutants, ammonia, cyanide, phenols, and solvent extractables have improved the bacterial, aesthetic and other properties of the harbour waters.

Status of Remedial Action Plan (Ranking by Ontario)

Comprehensive management strategy considering possible management options being prepared in cooperation with local agencies.

(Reference: The 1985 Report of the Great Lakes Water Quality Board)

EXHIBIT II

STAKEHOLDER GOALS

1. Recreational Boating
   Immediate action should be taken to improve water quality for recreational boating, on a continuing basis, for the total Harbour.

2. Water Sports
   THAT, on an area specific basis, water quality should be improved to permit increased use of the Harbour for water sports on a continuing basis.

3. Shipping and Navigation
   Shipping and navigation uses should continue and be contained in certain areas of the Harbour, with a view to reducing negative water quality impacts.

4. Industrial Uses
   THAT, the quality of the Harbour water should be improved to permit continuation of industrial uses.

   THAT, industrial water uses should continue in certain areas of the Harbour, and that effluent discharges should meet Ministry of the Environment guidelines.

5. Waste Water Receiving Body
   THAT, the Harbour's current status as a waste water receiving body be changed, so that it becomes a recipient of acceptable effluent, in specific areas;

   THAT, a loadings-target approach be established for point and non-point pollutant sources, and linked to all other uses to ensure effluent quality does not impede other uses.

6. Fisheries
   Water quality and fish habitat should be improved to permit an edible, naturally reproducing fishery for warm water species. Water and habitat conditions in Hamilton Harbour should not limit natural reproduction and the edibility of cold water species.

7. Wildlife Appreciation and Habitat Appreciation
   Water quality improvements should be made to permit an enhanced wildlife habitat on a Harbour-wide basis.

8. Swimming
   Providing that water quality meets appropriate health standards in the west end to support swimming as a use, water quality be enhanced to permit swimming, in the short term, and

   In the event that fecal coliform counts exceed water quality objectives for human contact, consideration should be given to using disinfectants and suitable membrane barriers to permit swimming, in the short term; and

   Hamilton Harbour water quality should be improved so that it (a) provides for swimming in certain areas of the Harbour over the long term; and (b) has no impact on water quality for swimming in nearshore Lake Ontario.

EXHIBIT III

1. OVERALL FACTORS - THE FOCUS ON THE HARBOUR

   (a) Ensure that public review procedures existing result in adequate assessment of the impact of new harbour developments on water quality and harbour habitat.

   (b) Provide ACCESS to Harbour

   (c) Address concerns about obnoxious odours and dust fallout.

   (d) Landscaping to be developed

   (e) Carry out a Market Survey for an improved harbour

   (f) Assessment of the capacity of the harbour for various uses

   (g) Operate Information Program for the general public and for students.

2. WATER QUALITY CONTROL ACTIONS

   (a) POINT SOURCES - Municipal, Industrial

   (b) NON-POINT SOURCES - Combined Sewers, Storm Water, Streams

   (c) MANAGEMENT OF CONTAMINATED SEDIMENTS IN HARBOUR

   (d) DIRECT OXYGENATION OF HYPOLIMNION IN SUMMER

   (e) SPILL CONTROL

   (f) LANDFILL LEACHATE CONTROL

3. PHYSICAL FACTORS REQUIRING ATTENTION

   (a) DEVELOP OR IMPROVE HABITAT FOR FISH AND WILDLIFE

   - enhanced emergent vegetation
   - enhanced submerged vegetation
   - interruption of wind generated turbidity
   - control/accommodation for fluctuating water levels

   (b) INDUSTRIAL INTAKE FISH IMPINGEMENT CONTROLS

   (c) MOVEMENTS OF LARGE VESSELS

   (d) INFILLING OF THE HARBOUR

EXHIBIT IV

OBSERVATIONS ON LIMITING FACTORS

USES

Limiting Factors	Swimming	Warm Water Fishery	Cold Water Fishery	Wildlife	Boating & Water Sport	Aesthetics
Reduced Oxygen		X	X			
Ammonia		X	X			X
Nutrients (Phosphorus)	X	X	X	X	X	X
Turbidity	X	X	X	X	X	
Carp		X		X		X
Metals		X	X	X		
Persistent Organics	X	X	X	X		
Bacteria	X				X	
Temperature		X	X			
Water Levels		X	X	X		
Infilling	X	X	X	X		X

Notes: Turbidity influences all desired uses
Nutrients influences all desired uses, partly because it affects turbidity or the clarity of the water

FIGURE 1. AREAS OF CONCERN IN THE GREAT LAKES BASIN

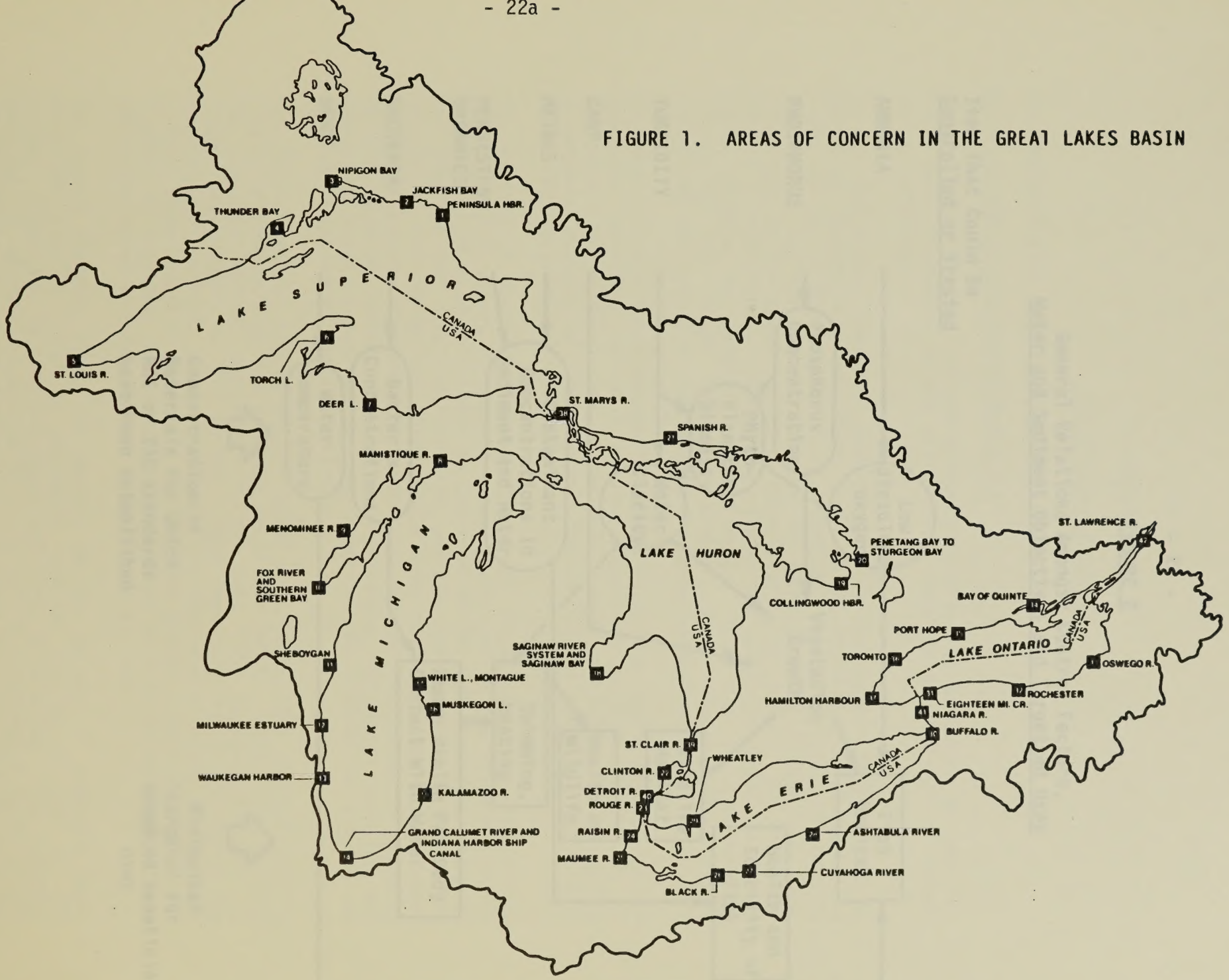
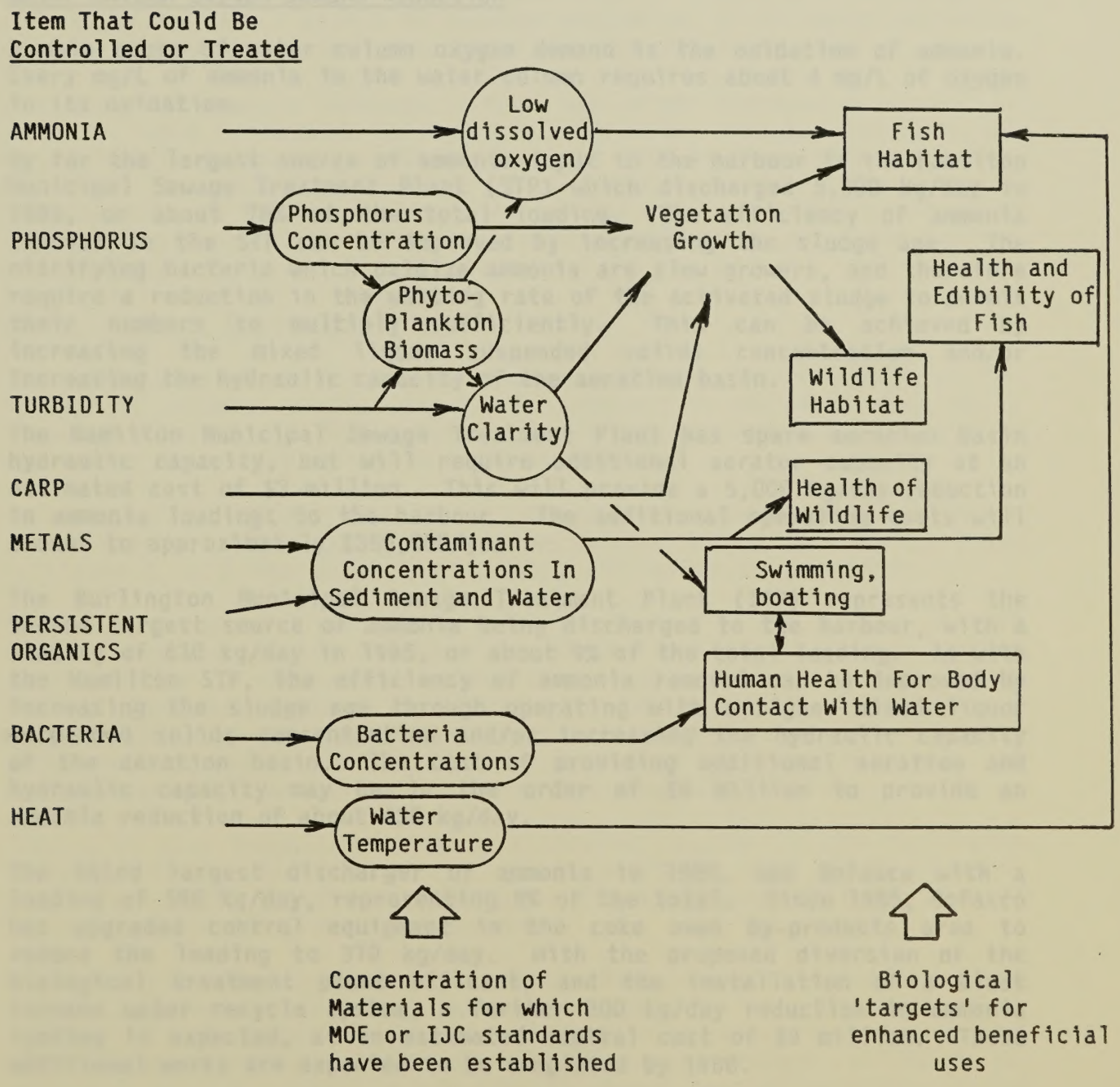
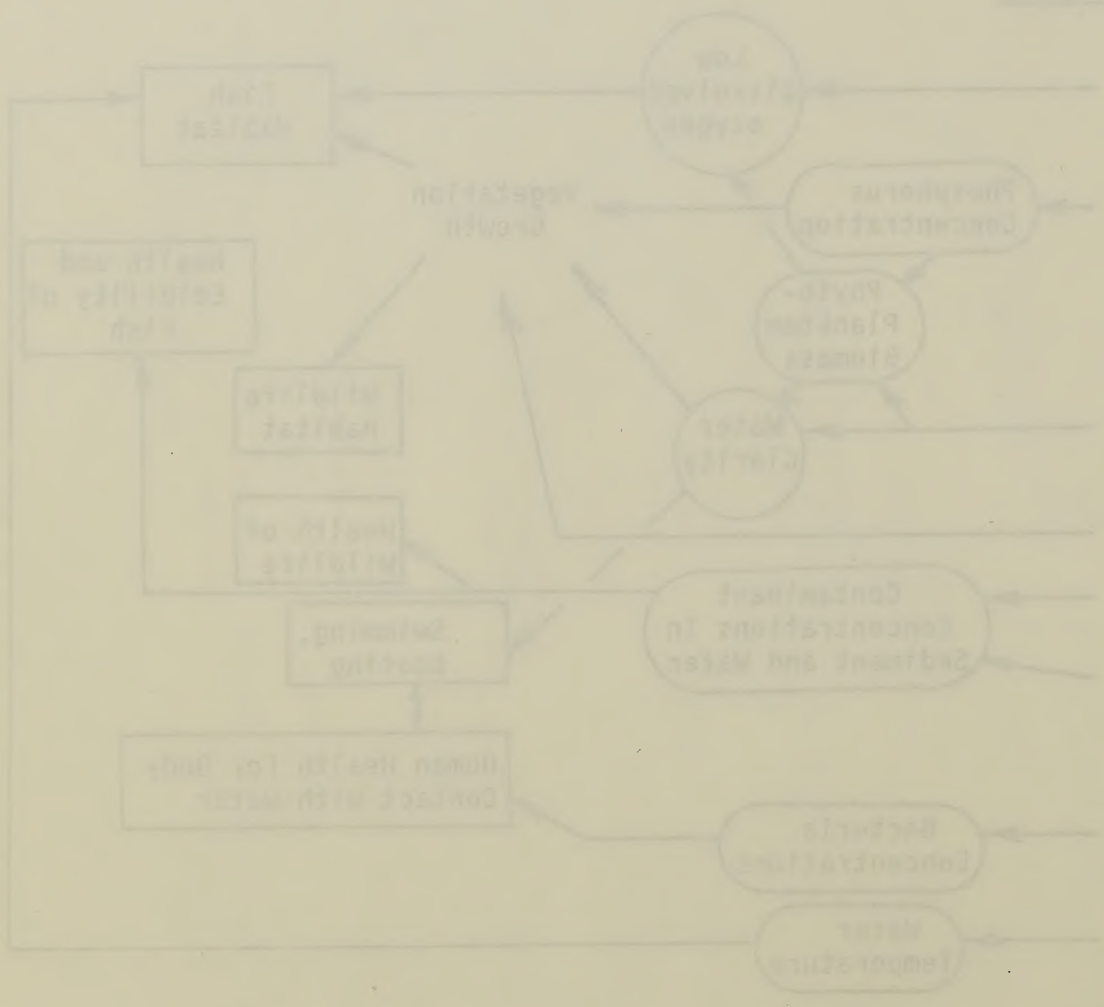


FIGURE 2

General Relations Amongst Control Factors,
Water and Sediment Objectives and Targetted Uses





APPENDIX 1

Source Control Options

Increasing Oxygen Levels in Harbour

Water Column Oxygen Demand Reduction

A main cause of water column oxygen demand is the oxidation of ammonia. Every mg/L of ammonia in the water column requires about 4 mg/L of oxygen in its oxidation.

By far the largest source of ammonia input to the harbour is the Hamilton Municipal Sewage Treatment Plant (STP) which discharged 5,500 kg/day in 1985, or about 78% of the total loading. The efficiency of ammonia removal in the STP can be improved by increasing the sludge age. The nitrifying bacteria which oxidize ammonia are slow growers, and therefore require a reduction in the wasting rate of the activated sludge to permit their numbers to multiply sufficiently. This can be achieved by increasing the mixed liquor suspended solids concentration and/or increasing the hydraulic capacity of the aeration basin.

The Hamilton Municipal Sewage Treatment Plant has spare aeration basin hydraulic capacity, but will require additional aerator capacity at an estimated cost of $3 million. This will provide a 5,000 kg/day reduction in ammonia loadings to the harbour. The additional operating costs will amount to approximately $350,000/year.

The Burlington Municipal Sewage Treatment Plant (STP) represents the second largest source of ammonia being discharged to the harbour, with a loading of 630 kg/day in 1985, or about 9% of the total loading. As with the Hamilton STP, the efficiency of ammonia removal can be improved by increasing the sludge age through operating with a higher mixed liquor suspended solids concentration and/or increasing the hydraulic capacity of the aeration basin. The cost of providing additional aeration and hydraulic capacity may be in the order of $6 million to provide an ammonia reduction of about 430 kg/day.

The third largest discharger of ammonia in 1985, was Dofasco with a loading of 590 kg/day, representing 8% of the total. Since 1985, Dofasco has upgraded control equipment in the coke oven by-products area to reduce the loading to 370 kg/day. With the proposed diversion of the biological treatment plant effluent, and the installation of a blast furnace water recycle system, a further 200 kg/day reduction in ammonia loading is expected, at an estimated capital cost of $9 million. These additional works are expected to be completed by 1988.

The fourth largest source of ammonia to the harbour is combined sewer overflows (cso's), with an estimated average loading in 1985 of 200 kg/day. There are 26 combined sewer overflows in Hamilton. The regional Municipality of Hamilton-Wentworth is installing a retention basin at one of the larger sewers to collect the overflow for pumping back into the sewer system for treatment after storm occurrences. The facility is expected to be completed in April 1987, at a cost of $5 million. The

cost of installing storage basins to control all combined sewer overflows is estimated to be about $60 million. The Regional Municipality is currently seeking funds to develop a computerized system to optimize the storage capacity of the existing sewers. Such a system may reduce the overall cost of controlling combined sewer overflows.

The fifth largest source of ammonia discharge is Stelco with a loading of 156 kg/day in 1985. Stelco is nearing completion of its water pollution control program and further reductions are expected to be minor.

A summary of ammonia loadings before and after improved treatment is shown in Table 1 and also in Figure 1. The total ammonia loading to the harbour could be reduced by about 85% from 1985 loadings with completion of all improvement programs. This should reduce the ammonia concentration in the harbour to less than 0.5 mg/L. A reduction of about 83% should be attainable within a 3 year period, at an estimated cost of $19 million.

Sediment Oxygen Demand Reduction

The other major cause of oxygen depletion in the bottom waters of the harbour is sediment oxygen demand. This demand is believed to be mostly internally generated. Algae which grow in the surface waters settle to the bottom where they decompose using up oxygen.

To reduce algal growth it will be necessary to reduce phosphorus inputs to the harbour. The loadings discharged to the harbour in 1985 are shown in Figure 2, with the total loading being 609 kg/day as phosphorus.

The largest source of phosphorus being discharged to the harbour in 1985 was the Hamilton Municipal Sewage Treatment Plant (STP), with a loading of 399 kg/day as phosphorus. Since 1985, improvements in the operation of the plant have reduced the loading to 220 kg/day as phosphorus. A further reduction to about 93 kg/day as phosphorus should be achievable with the installation of a filtration system on the final effluent. It is estimated that such as system would cost about $35 million.

Similarly, the installation of a filtration system at the Burlington Municipal Sewage Treatment Plant, at an estimated cost of $7 million, would reduce the phosphorus loading in the Burlington effluent from 47 kg/day to about 20 kg/day as phosphorus.

Other sources of phosphorus input to the harbour include combined sewer overflows, creeks, and storm sewer discharges. It is estimated that an average of 78 kg/day as phosphorus are being discharged by way of combined sewer overflows. The provision of sewage storage facilities, as described earlier, should reduce the phosphorus loading from this source to about 5 kg/day as phosphorus.

Phosphorus in the creeks is believed to be mostly from soil erosion at construction sites, along stream banks, and of farm land. Reduction of erosion through more stringent controls are construction sites, installation of retention devices to minimize peak stream flows and/or structures to protect stream banks, and changing farm practices could

possibly reduce the phosphorus input from these sources by one-half. More field work is needed to determine the significance of each of these sources before an estimate can be made of the actual reduction attainable and its costs.

Thus with implementation of best available technology at point sources and reducing non-point loadings by 50%, the total phosphorus loading to the Harbour can be reduced to about 163 kg/day. It is estimated that such changes would reduce the average annual phosphorus concentration in the Harbour to about 34 mg/cu m which is still above the Provincial water quality guideline of 20 mg/cu m and does not leave any room for future increased sewage flows.

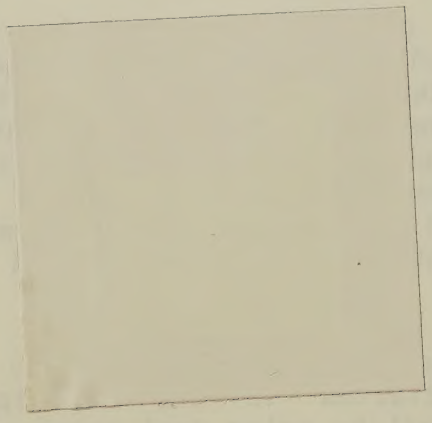
The above loading calculations are based on the present sewage flows at the Hamilton and Burlington municipal sewage treatment plants. As growth occurs, sewage flows and phosphorus loadings will increase. The design capacities of the secondary treatment stage of the present Hamilton plant is 409,000 cu m/day and of the present Burlington plant is 93,000 cu m/day. If sewage flows increase to plant design capacities the total phosphorus loadings to the Harbour with best available control technology will increase to 197 kg/day. The average annual phosphorus concentration in Hamilton Harbour would increase to 36 mg/cu m as compared to 34 with no increases in sewage flows.

At present, the algal growth in the Harbour is not limited by phosphorus. The point at which phosphorus will limit growth is difficult to predict. A reduction of phosphorus in the Harbour to 34 mg/cu m may only reduce the annual algal growth by between 15 and 34%. Thus, the reduction in phosphorus loading to 163 kg/day may result in little noticeable improvement in water clarity. Such reduction also may not reduce the internally generated oxygen demand resulting form algal growth adequately to maintain a desireable level of dissolved oxygen in the Harbour waters.

Short term studies indicate that it may be possible to reduce the phosphorus concentration in the municipal sewage treatment plant effluents to 0.1 mg/l by using dual point chemical addition. The second point of chemical addition would occur immediately prior to the filters. More extensive experimentation would be required to determine the viability of such technology.

If the phosphorus concentration in municipal sewage treatment plant effluents could be reduced to 0.1 mg/l with a 50% reduction in creek inputs and elimination of combined sewer overflows the phosphorus loading to the Harbour would be 89 kg/day. The average phosphorus concentration in the Harbour would then be about 23 mg/cu m or slightly in excess of the Provincial water quality guideline of 20 mg/cu m. The water clarity would be expected to improve and the internally generated oxygen demand would be reduced by 40 to 60%.

It sewage flows were to increase to plant design capacities, the total phosphorus loadings to the harbour with dual point chemical injection would increase to 100 kg/day and the phosphorus concentration in the Harbour would be 26 mg/cu m as compared to 23 with no increases in sewage flows.



Little additional operating and capital cost would be required for dual point chemical addition. Studies carried out in Switzerland indicate that an effluent phosphorus concentration of 0.1 mg/l can be attained using dual point injection with the same chemical usage as required in single point injection to attain 0.3 mg/l. The Hamilton sewage treatment plant now relies on iron in the incoming sewage treatment plant now relies on iron in the incoming sewage to precipitate the phosphorus. The Hamilton plant would therefore have to install a chemical storage tank and feeder pump to add in the order of 5 mg/l of iron salt immediately prior to the filters. Purchase of chemical for the second injection point would cost in the order of $200,000 per year. The operating cost would also increase as a result of the need for more frequent backwashing of the filters and increased volumes of sludge being produced. The Burlington sewage treatment plant already has chemical feeding equipment. It would require a second feed pump and piping to inject immediately prior to the filters a portion of the chemical now being injected at the front of the plant.

An alternative to installing best available treatment at the municipal sewage treatment plants would be diversion of the effluents directly into Lake Ontario. Such a step combined with elimination of combined sewer overflows and reduction of creek inputs by 50% would reduce the phosphorus loading to the Harbour to about 50 kg/day. The phosphorus concentration in the Harbour would then be reduced to about 19 mg/cu m meeting the Provincial water quality guideline. This concentration is close to that now occurring in the near shore waters of Lake Ontario. A very noticeable improvement in water clarity would therefore be expected. As well the internally generated oxygen demand would be reduced by about 70%.

Discharge of the treated effluents directly to Lake Ontario would require careful study of lake currents to ensure proper placement of the outfalls. Such careful placement would be necessary to ensure that the effluents do not impair water quality at the water intakes nor at the beaches. The costs of the outfalls would be dependent on the distance that they would have to be placed from shore. The construction of an outfall to discharge the Hamilton treated effluent into the lake two kilometers from shore would cost approximately $20 million. The cost of locating the outfall three kilometers from shore would be in the order of $26 million.

A summary of the phosphorus loadings from each of the sources is shown in Figure 2 for 1985 and for each of the options. A summary of the total loadings of phosphorus to the harbour for 1985 and each of the options is shown in Table II. And Figure 3 summarizes total phosphorus loadings for both present and design sewage flows. The costs of each of the options for reducing the phosphorus loadings to the Harbour are summarized in Table III.

Other Factors Affecting Rehabilitation of Fishery

Hamilton Harbour

Another factor identified as limiting pike rehabilitation in Hamilton Harbour is the scarcity of submerged aquatic macrophytes. Light

extinction in the water column restricts light penetration to the harbour bottom and therefore limits the ability of macrophytes to grow. Light extinction is believed to be caused mainly by algae, and suspended solids from streams resulting from soil erosion during periods of high runoff. The measures described earlier to reduce algal growth by controlling phosphorus inputs, and to reduce soil erosion, should increase water clarity and therefore the growth of macrophytes.

Prediction of water clarity is difficult. Algae concentrations have been a main cause of water turbidity. Algal growth has not been limited by phosphorus concentration in Hamilton Harbour. As the phosphorus loading to the Harbour is reduced, a point will be reached where phosphorus availability will limit algal growth. The concentration at which phosphorus will be limiting is not easily predicted.

An annual average phosphorus concentration in the Harbour of 34 mg/cu m can be attained by installing filters at the municipal sewage treatment plants, eliminating combined sewer overflows and reducing non-point sources by 50%. Reducing the phosphorus concentration to 34 mg/cu m may reduce the amount of algal growth by only between 15 to 35%. As a result little improvement in water clarity would be expected.

If reduction of phosphorus in the municipal sewage treatment plants to 0.1 mg/l in the Harbour should prove feasible , the concentration in the Harbour could be reduced to 23 mg/cu m. At that concentration, phosphorus should limit algal growth. As a result water clarity should improve with Secchi disc depth readings of 1.5 to 2 meters being attained. Still greater water clarity would occur with diversion of the municipal sewage treatment plant effluents directly to Lake Ontario. Secchi disc depth readings of 2 to 2.5 meters would be expected. Such water clarity will permit sufficient light to reach the Harbour bottom in the shallower areas for macrophyte growth. The harbour water average annual total phosphorus concentrations in 1985, and for each of the abatement options are shown in Figure 4. The Harbour water quality improvement expected from each of the Abatement options is summarized in Figure 5.

In the late 1970's, zinc concentrations in the harbour were found at times to exceed Provincial Water Quality Objective. The largest source of zinc was found to be the Stelco blast furnaces. Since then, Stelco has installed blast furnace water recirculation systems with blowdown treatment. These works were completed in 1982. Provincial water quality criteria are now being met.

Although analysis for specific priority organic pollutants was not carried out until recently, it is believed that the control works installed for conventional pollutants also significantly reduced priority organic pollutant loadings to the harbour. For instance, the loading of total polynuclear aromatic hydrocarbons in point source discharges was only 1.5 kg/day in 1985. With completion of the steel mills, it is expected that the 1 kg/day.

The effect on fish of contaminants in bottom sediments in the harbour is not known at this time. Further research is needed to determine what effect they may have and what improvements may be needed.

Cootes Paradise

Extensive macrophyte beds at one time existed in Cootes Paradise. These have gradually been disappearing and now occupy only small areas of Cootes Paradise. This reduction is believed to be caused by water turbidity resulting in macrophyte seedlings not receiving sufficient light to grow. Causes of the turbidity include algal growth, stirring up of bottom sediments by wave action and activity of carp and by soil eroded from the watershed.

Cootes Paradise is a very eutrophic body of water. As a result of high nutrient concentrations high algal growth occurs during the spring and summer. The algae in the water column shade the bottom. When the algae die, they create a bottom sediment which is very easily stirred up by wave action and activities of carp.

Phosphorus inputs must be reduced to control algal growth. The retention time in Cootes Paradise is only 2.7 days on average during the year and about 20 days during the summer low flow period. Control of available phosphorus inputs during the peak, algal growing season of mid April to mid September is important.

The Dundas sewage treatment plant is the biggest source of phosphorus input to Cootes Paradise during the critical algal growing season with 7.3 kg/day being discharged in 1985. The Regional Municipality of Hamilton Wentworth is proposing to install filters at the Dundas plant. Filters will reduce the phosphorus loading from the plant to about 2.7 kg/day. As sewage flows increase to the design capacity of the plant, the phosphorus loadings could rise to about 3.6 kg/day.

The creeks represent the second largest source of available phosphorus. The available phosphorus inputs from the creeks during the critical algal growing season is estimated to be about 3.4 kg/day. Further studies are required to identify the sources of this phosphorus and the abatement action that can be taken. It is reasonable to expect, however, that at least a 50% reduction can be attained. The contribution from creeks therefore can probably be reduced to about 1.7 kg/day.

The third largest input of phosphorus to Cootes Paradise is derived from Hamilton Harbour. The loading in 1985 is estimated to be 2 kg/day. With the use of best available technology to control inputs to Hamilton Harbour, the contribution of Hamilton Harbour to Cootes Paradise would be expected to be reduced to about 0.7 kg/day.

The fourth largest source of phosphorus discharge to Cootes Paradise is the Hamilton combined sewer overflows. The loading from this source is estimated to be 1.6 kg/day during the critical algal growing season. Installation of facilities to retain combined sewer overflows can probably reduce the loading from this source to less than 0.1 kg/day.

By implementing best available technology as described above, the available phosphorus loading to Cootes Paradise during the critical algal growing season will be reduced from 14.3 kg/day in 1985 to about 5 to 6 kg/day depending on the Dundas sewage flows. The phosphorus

concentration in Cootes Paradise would be reduced to about 58 mg/cu m. The turbidity caused by algae would therefore be reduced by about 40%.

The use of dual point chemical injection as described earlier could reduce the phosphorus input from the Dundas municipal sewage treatment plant to about 1.2 kg/day. The phosphorus concentration in Cootes Paradise would then be reduced to 38 mg/cu m. The turbidity caused by algae would be reduced to about on-half present levels.

A third option would be to pump the Dundas sewage into the Hamilton sewers and to shut down the Dundas plant. The total available phosphorus loading to Cootes Paradise would then be reduced to about 2.5 kg/day during the critical algal growing season. The phosphorus concentration in Cootes Paradise would then be about 28 mg/cu m. The turbidity caused by algae would be reduced by about 60% from present levels. The available phosphorus loadings to Cootes Paradise from each of the sources are summarized in Figure 6 for 1985 and each of the three possible abatement options. The total available phosphorus loadings to Cootes Paradise are shown in Figure 7. Average concentrations of total phosphorus in 1985 and for each of the abatement options during the critical algal growing season are shown in Figure 8. Water quality improvements in Cootes Paradise resulting from implementation of the above three options are summarized in Figure 9.

Soil erosion adds to the turbidity. The most common practice in the construction of subdivisions is to first strip off the top soil. The sewers and water mains are then installed and the homes and streets constructed. The top soil is then replaced and the lots sodded. Between the stripping of the top soil and resodding, the erosion rates are very high. With development, the water retention capabilities are reduced resulting in more rapid runoff of precipitation. The more rapid runoff in turn causes higher peak stream flows resulting in increased erosion of stream beds and banks. As well the trend in the farming community has been towards the planting of more row crops such as corn. Soil is less protected from erosion with these crops. Measures to control soil erosion include settling basins for runoff from construction sites, storm retention basins to reduce peak storm flows, installing rip rap on creek beds and banks susceptable to erosion and modifying farm practices to minimize soil loss.

Carp also cause turbidity by stirring up the bottom sediments during their activities. They also uproot aquatic plants. Reducing algal growth should result in a more compact sediment less susceptable to being stirred up. It has been found elsewhere that pike will control the carp population by feeding on the young carp. Thus improving the environment for pike should result in an increase in the pike population which in turn should reduce the carp population. Encouraging a commercial fishery for carp would be another way of controlling the carp population.

The Royal Botanical Gardens along with Ducks Unlimited is considering installing dykes in Cootes Paradise to create cells isolated from the sources of pollution. Pumping would be provided to control the water levels in the cells to optimize the growth of macrophytes to support

waterfowl. The dykes would keep carp out of the cells and would channel the pollution from streams and the Dundas sewage treatment plant directly into Hamilton Harbour.

The project would optimize conditions in Cootes Paradise for the production of waterfowl. It would minimize the access of carp to Cootes Paradise but could also impact upon desirable fish species. Methods of permitting access to the cells for desirable fish species are being investigated. By channelling the stream and sewage treatment plant outflows, the pollutant loadings to Hamilton Harbour would be increased.

Wildlife Habitat

Re-establishment of marsh areas is necessary to increase marsh habitats. Improvement of water clarity by reducing algal growth and sediment load from erosion will aid expansion of marsh areas.

Other factors believed to be affecting the re-establishment of marsh areas, especially in Cootes Paradise, include high water levels, the disturbance of bottom sediments by wave action, and the activities of carp. Areas can be dyked off to permit the control of water levels, sedimentation, and access to carp. The impact of such structures on desirable fish species must be considered.

Boating and Other Water Sports

The improvements already outlined will also make Hamilton Harbour more suitable for boating and other water sports. The control of combined sewer overflows, treatment of storm water where necessary, and improved removal efficiencies of suspended solids at the municipal sewage treatment plants will reduce the coliform counts in the harbour. Improved removal of suspended solids at municipal sewage treatment plants, control of combined sewer overflows, and improved stream erosion control will reduce phosphorus inputs, and thus reduce algal growth, resulting in greater water clarity. This along with landscaping will make the harbour more aesthetically pleasing for boating and other water sports.

Swimming

To make the harbour suitable for swimming it is necessary to control the sources of coliform bacteria. These sources include combined sewer overflows, sewage treatment plant effluents, and storm sewer discharges.

The Regional Municipality of Hamilton-Wentworth has initiated a program for providing containment of sewage during times of precipitation to minimize combined sewer overflows. This program is described under the program for controlling ammonia discharges. It is estimated that $60 million may be needed to control combined sewer overflows. At the present rate of commitment of funds, the Regional Municipality will take in the order of 20 years to complete the program. If funds were not limiting, the combined sewer overflows could probably be controlled within 5 years.

Municipal sewage treatment plant effluents remain a source of coliform bacteria even though chlorination is being practiced to disinfect the effluent. Chlorine must directly contact the bacteria to destroy them. Suspended solids in the effluent reduce the effectiveness of chlorination as bacteria within the particles are protected from direct contact with chlorine. Filtration of the sewage treatment plant effluent, as described earlier to reduce phosphorus inputs will reduce suspended solids concentrations, and therefore increase the effectiveness of disinfection.

Storm sewer discharges can contribute to coliform counts. Further monitoring is needed to determine where storm water may be affecting water quality and where treatment of storm water may be necessary.

A reduction of algal growth by controlling phosphorus inputs will increase water clarity. This will make the harbour aesthetically pleasing for swimming.

Aesthetics

Some landscaping along the shoreline of the Stelco and Dofasco properties has been undertaken. Both companies are continuing with their landscaping programs with completion expected in 1991. Other industries bordering the harbour are also being asked to provide landscaping.

Air pollution control programs are nearing completion with the last control measures scheduled to be completed in 1989.

Completion of the water pollution control measures as outlined under rehabilitation of the fishery will also improve the aesthetics of the harbour water.

The clean-up options for Windermere Basin have been reviewed. Isolating portions of the basin by constructing dykes and then placing contaminated sediment into these dyked areas would appear to be the optimal method of clean-up. Financing for the project is presently being sought. A summary of the costs to improve harbour aesthetics is shown in Table III.

TABLE I

Ammonia Loadings to Hamilton Harbour

Source	Loadings in 1985 kg/day as N	Loadings with Available Technology kg/day as N	Estimated Capital Cost $ million	Minimum Time Requirement For Completion
Hamilton STP	5,500	500	3	2 1/2 yrs.
Burlington STP	630	200	6	3 yrs.
Dofasco	590	170	9	2 1/2 yrs.
Hamilton CSO	200	20	60	5 yrs.
Stelco	156	150	4	1/2 yr.
	7,076	1,040	82	

* Reduced to 340 kg/day with diversion of municipal sewage treatment plant effluents to Lake Ontario.

TABLE II

Phosphorus Loadings to Hamilton Harbour

Source	Loadings in 1985 kg/day as P	ABATEMENT OPTIONS: Best Available Technology kg/day as P	ABATEMENT OPTIONS: Possible Future Best Available Technlogy kg/day as P	ABATEMENT OPTIONS: Diversion of STP Effluents to Lake Ontario
Hamilton STP	399	93	31	
Burlington STP	47	20	7	
Hamilton CSO	78	5	5	
Creeks	80	40	40	
Storm Sewers	5	5	5	
Total	609	163	88	

TABLE III

Capital and Operating Costs (million)

	Best Available Technology		Possible Future Best Available Technology		Diversion of Effluent to Hamilton Harbour	
	Capital Cost	Annual Operating Cost	Capital Cost	Annual Operating Cost	Capital Cost	Annual Operating Cost
Hamilton STP						
Ammonia	3	0.35	3	0.35		
Phosphorus	35	0.08	36	0.30		
Total	38	0.43	39	0.65	26	0.04
Burlington STP						
Ammonia	6	0.10	6	0.10		
Phosphorus	9	0.03	10	0.05		
Total	14	0.13	16	0.15	18	0.02

TABLE IV

Costs Relating To Harbour Aesthetics

	Cost $ million	Minimum Time Requirement for Completion
Landscaping	1.8	5 years
Air pollution controls	33.5	3 years
Water pollution controls	90	5 years
Windermere Basin clean-up	4.5	1 year

FIGURE 1: HAMILTON HARBOUR

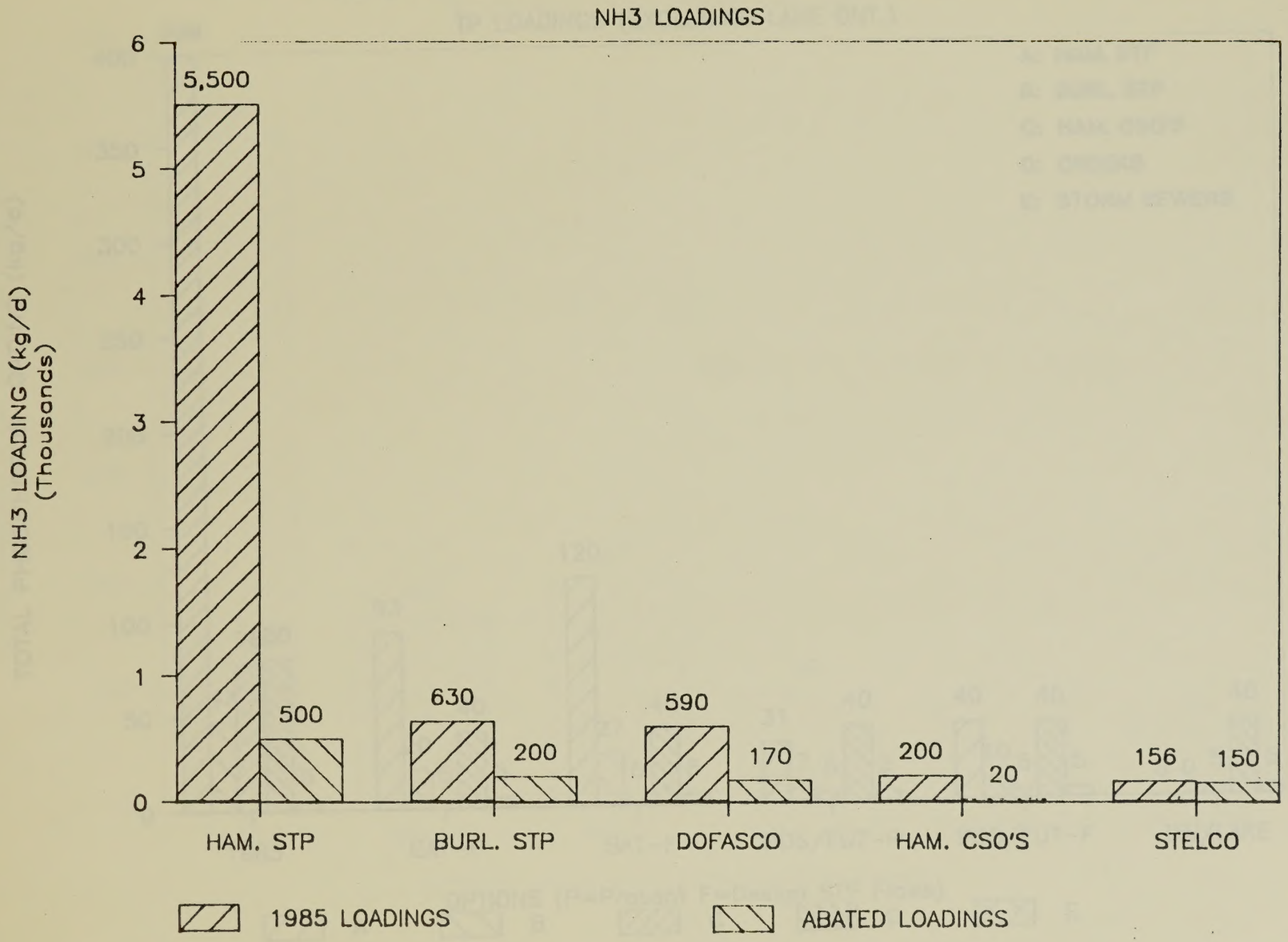


FIGURE 2: HAMILTON HARBOUR

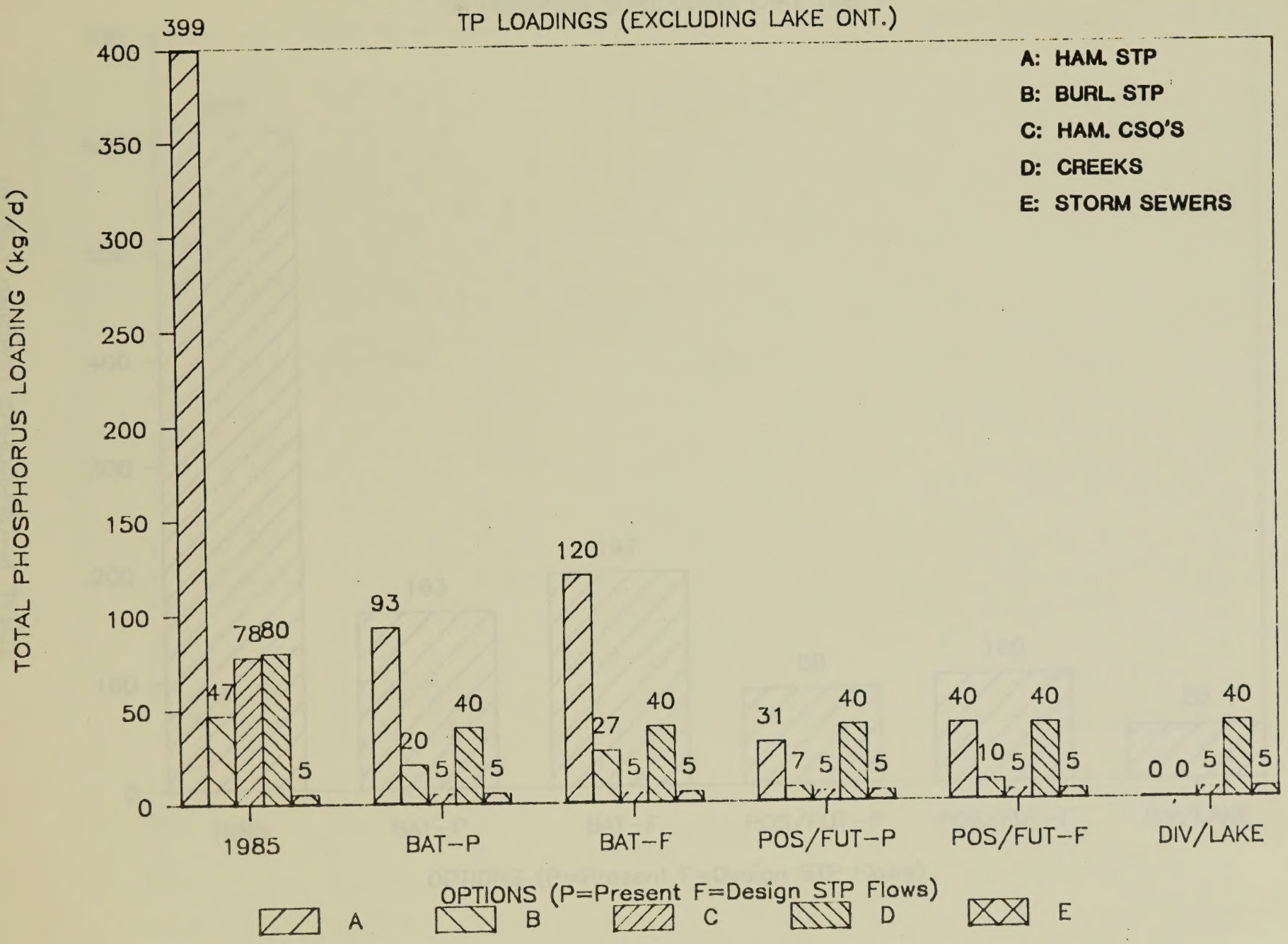
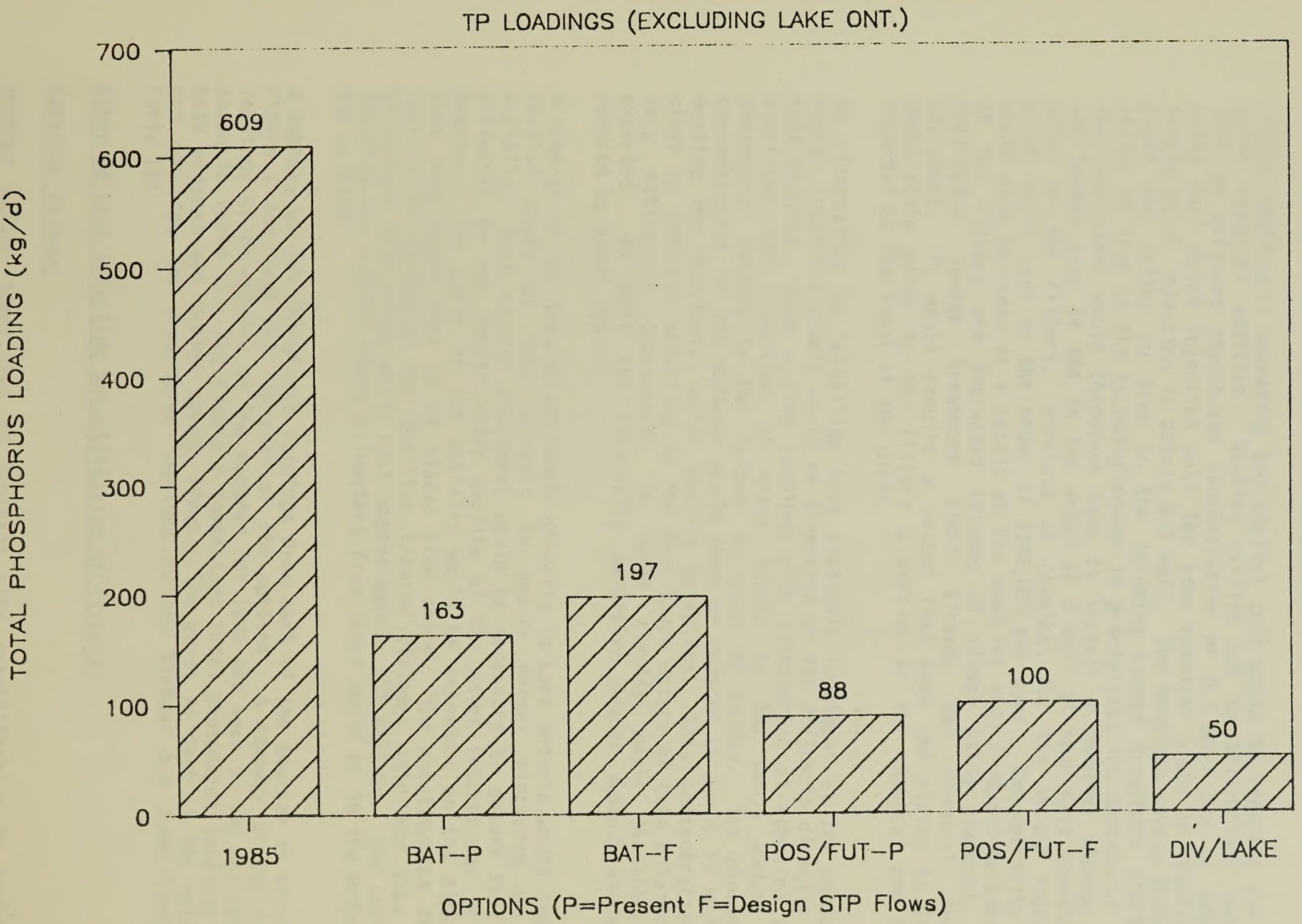


FIGURE 3: HAMILTON HARBOUR



Little additional operating and capital cost would be required for dual point chemical addition. Studies carried out in Switzerland indicate that an effluent phosphorus concentration of 0.1 mg/l can be attained using dual point injection with the same chemical usage as required in single point injection to attain 0.3 mg/l. The Hamilton sewage treatment plant now relies on iron in the incoming sewage treatment plant now relies on iron in the incoming sewage to precipitate the phosphorus. The Hamilton plant would therefore have to install a chemical storage tank and feeder pump to add in the order of 5 mg/l of iron salt immediately prior to the filters. Purchase of chemical for the second injection point would cost in the order of $200,000 per year. The operating cost would also increase as a result of the need for more frequent backwashing of the filters and increased volumes of sludge being produced. The Burlington sewage treatment plant already has chemical feeding equipment. It would require a second feed pump and piping to inject immediately prior to the filters a portion of the chemical now being injected at the front of the plant.

An alternative to installing best available treatment at the municipal sewage treatment plants would be diversion of the effluents directly into Lake Ontario. Such a step combined with elimination of combined sewer overflows and reduction of creek inputs by 50% would reduce the phosphorus loading to the Harbour to about 50 kg/day. The phosphorus concentration in the Harbour would then be reduced to about 19 mg/cu m meeting the Provincial water quality guideline. This concentration is close to that now occurring in the near shore waters of Lake Ontario. A very noticeable improvement in water clarity would therefore be expected. As well the internally generated oxygen demand would be reduced by about 70%.

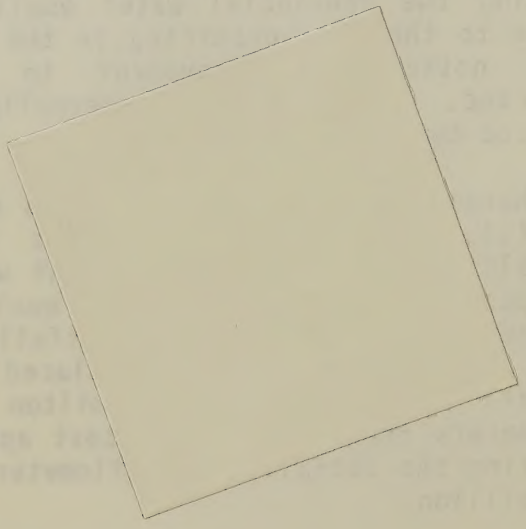
Discharge of the treated effluents directly to Lake Ontario would require careful study of lake currents to ensure proper placement of the outfalls. Such careful placement would be necessary to ensure that the effluents do not impair water quality at the water intakes nor at the beaches. The costs of the outfalls would be dependent on the distance that they would have to be placed from shore. The construction of an outfall to discharge the Hamilton treated effluent into the lake two kilometers from shore would cost approximately $20 million. The cost of locating the outfall three kilometers from shore would be in the order of $26 million.

A summary of the phosphorus loadings from each of the sources is shown in Figure 2 for 1985 and for each of the options. A summary of the total loadings of phosphorus to the harbour for 1985 and each of the options is shown in Table II. And Figure 3 summarizes total phosphorus loadings for both present and design sewage flows. The costs of each of the options for reducing the phosphorus loadings to the Harbour are summarized in Table III.

Other Factors Affecting Rehabilitation of Fishery

Hamilton Harbour

Another factor identified as limiting pike rehabilitation in Hamilton Harbour is the scarcity of submerged aquatic macrophytes. Light



7.0 REVIEW OF USES IN THE LIGHT OF THE POSSIBLE REMEDIAL ACTIONS

7.1 Wildlife Habitat

Re-establishment of marsh areas is necessary for habitat improvement. Improvement of water clarity by reducing algal growth and sediment load from erosion will aid expansion of marsh areas. Other factors believed to be affecting the re-establishment of marsh areas, especially in Cootes Paradise, include water levels, the disturbance of bottom sediments by wave action, and the activities of carp. Areas can be dyked off to permit the control of water levels, sedimentation, and access to carp. The impact of such structures on desirable fish species must be considered for any such development.

7.2 Boating and Other Water Sport

The improvements already outlined will also make Hamilton Harbour more suitable for boating and other water sports. The control of combined sewer overflows, treatment of storm water where necessary, and improved removal efficiencies for suspended solids at the municipal sewage treatment plants will reduce the coliform counts in the harbour. Improved removal of suspended solids at municipal sewage treatment plants, control of combined sewer overflows, and improved stream erosion control will reduce phosphorus inputs, and thus reduce algal growth, resulting in greater water clarity. This, along with landscaping, will make the harbour more aesthetically pleasing for boating and other water sports.

7.3 Swimming

To make the harbour suitable for swimming it is necessary to control the source of pathogenic bacteria. These sources include combined sewer overflows, sewage treatment plant effluents, and storm sewer discharges.

The Regional Municipality of Hamilton-Wentworth has initiated a program for providing containment of sewage during times of precipitation to minimize combined sewer overflows. This program is described under the program for controlling ammonia discharges (Appendix 1).

Municipal sewage treatment plant effluents remain a source of coliform bacteria even though chlorination is being practiced to disinfect the effluent. Chlorine must directly contact the bacteria to destroy them. Suspended solids in the effluent reduce the effectiveness of chlorination as bacteria within the particles are protected from direct contact with chlorine. Filtration of the sewage treatment plant effluent, to reduce phosphorus inputs will also reduce suspended solids concentrations, and therefore increase the effectiveness of disinfection.

FIGURE 4: HAMILTON HARBOUR

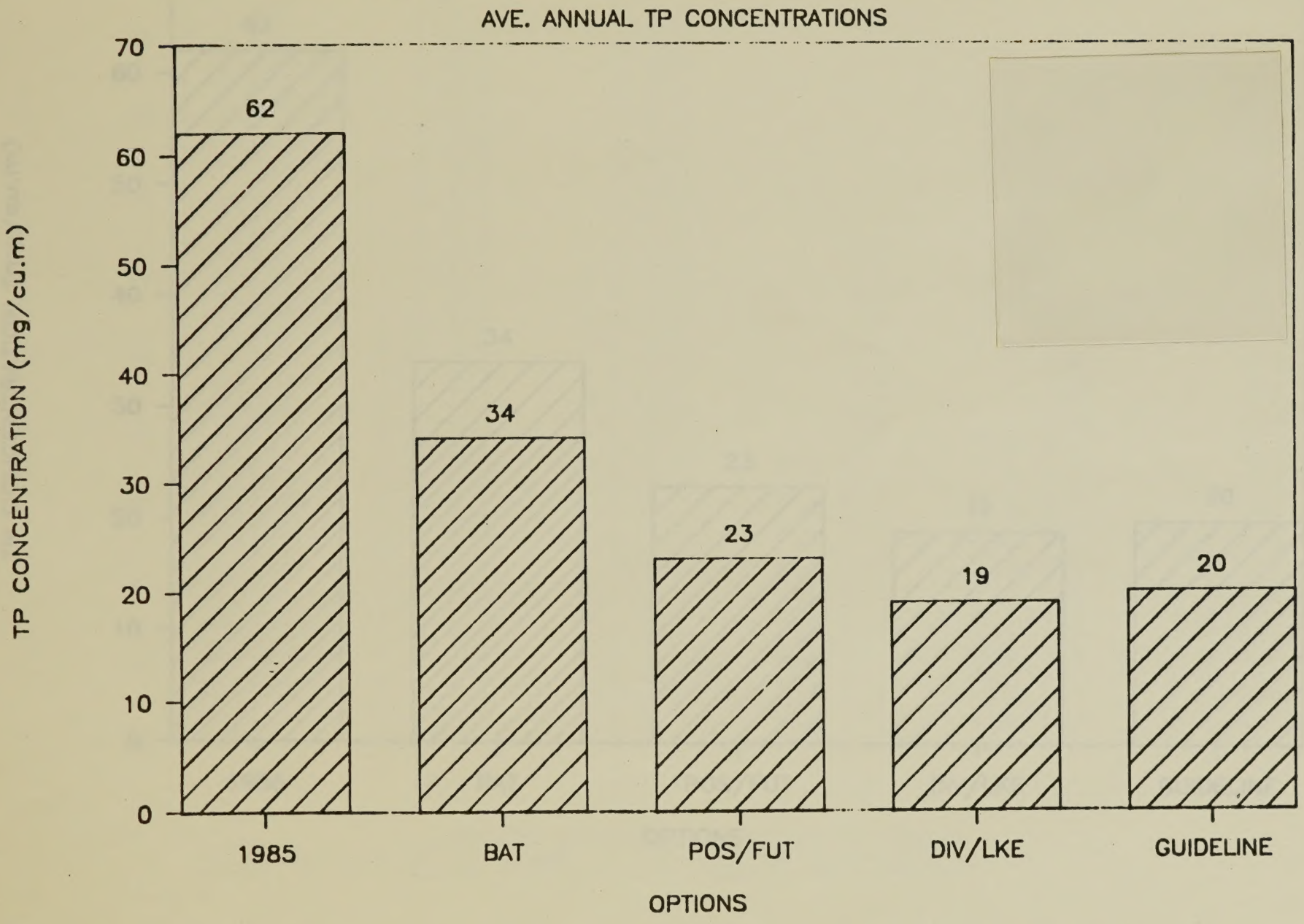


FIGURE 4: HAMILTON HARBOUR

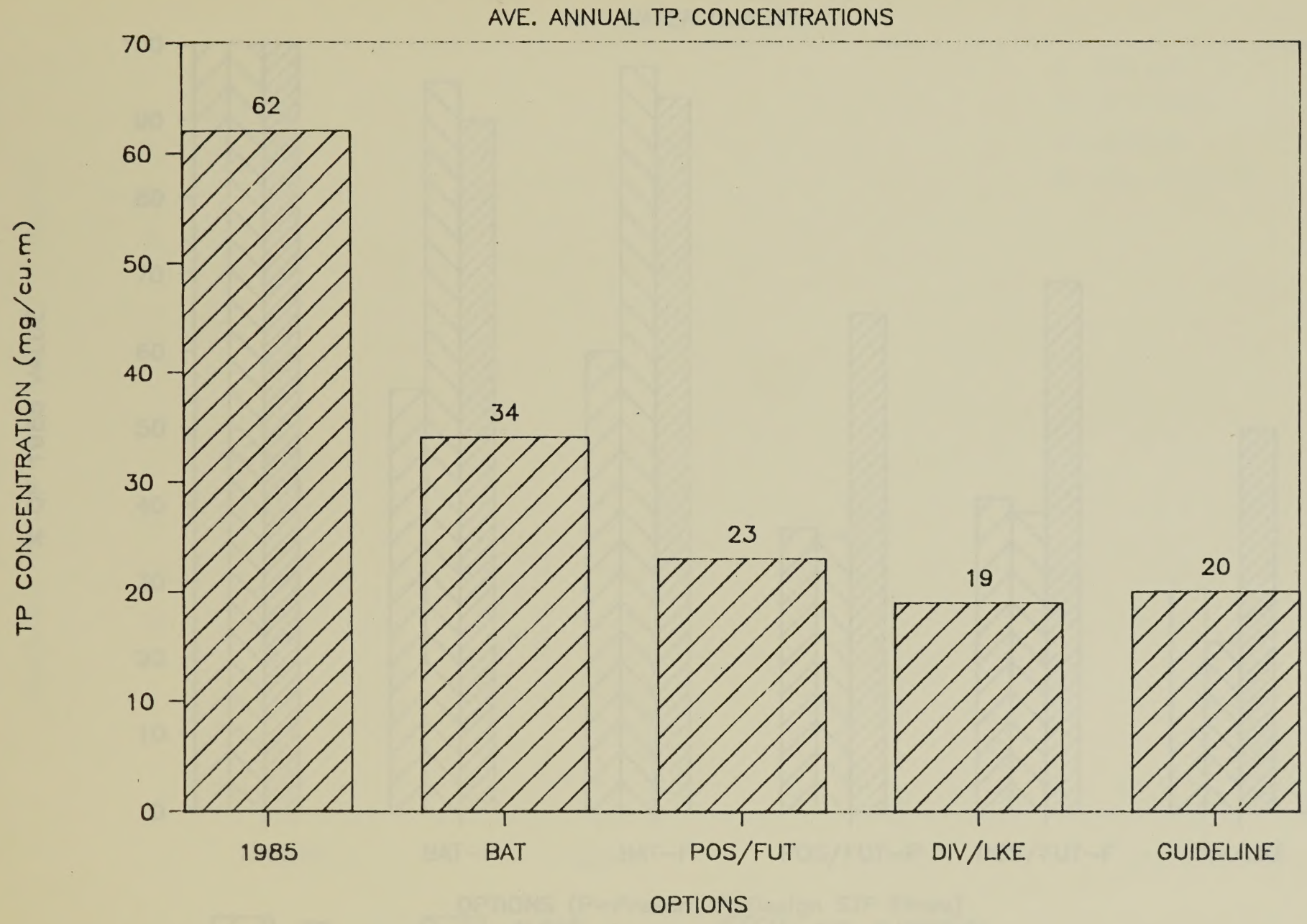
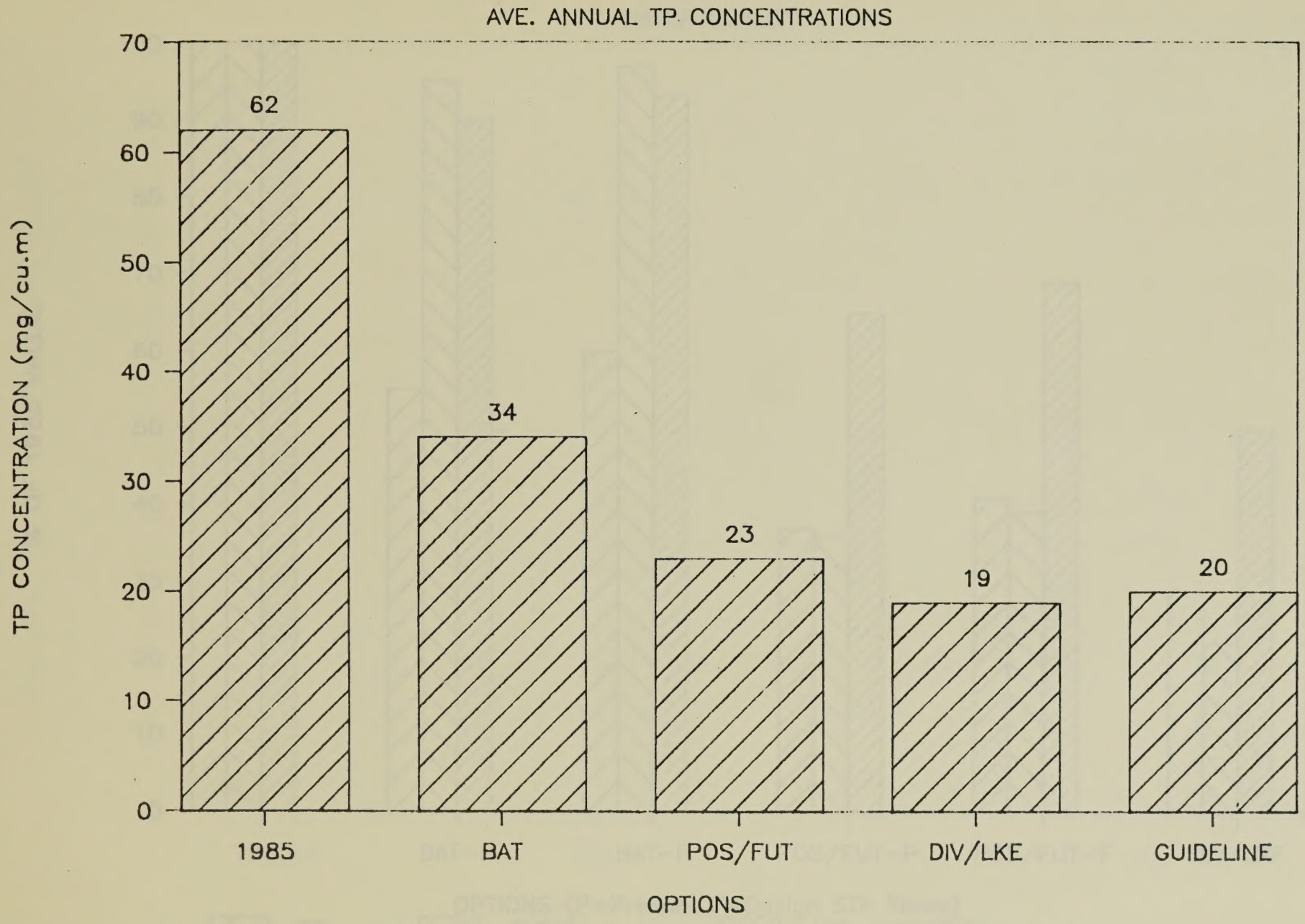


FIGURE 4. HAMILTON HARBOUR



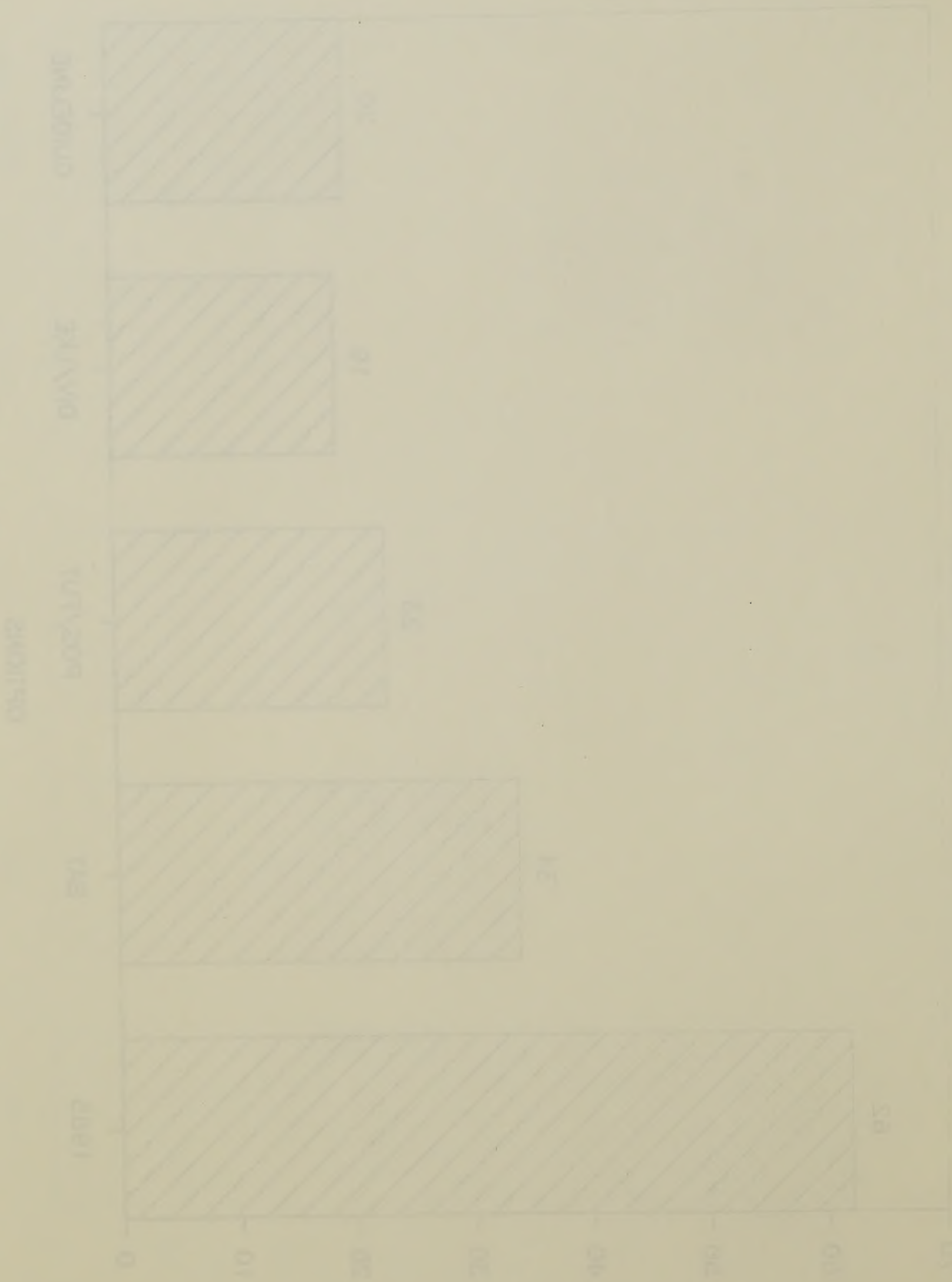
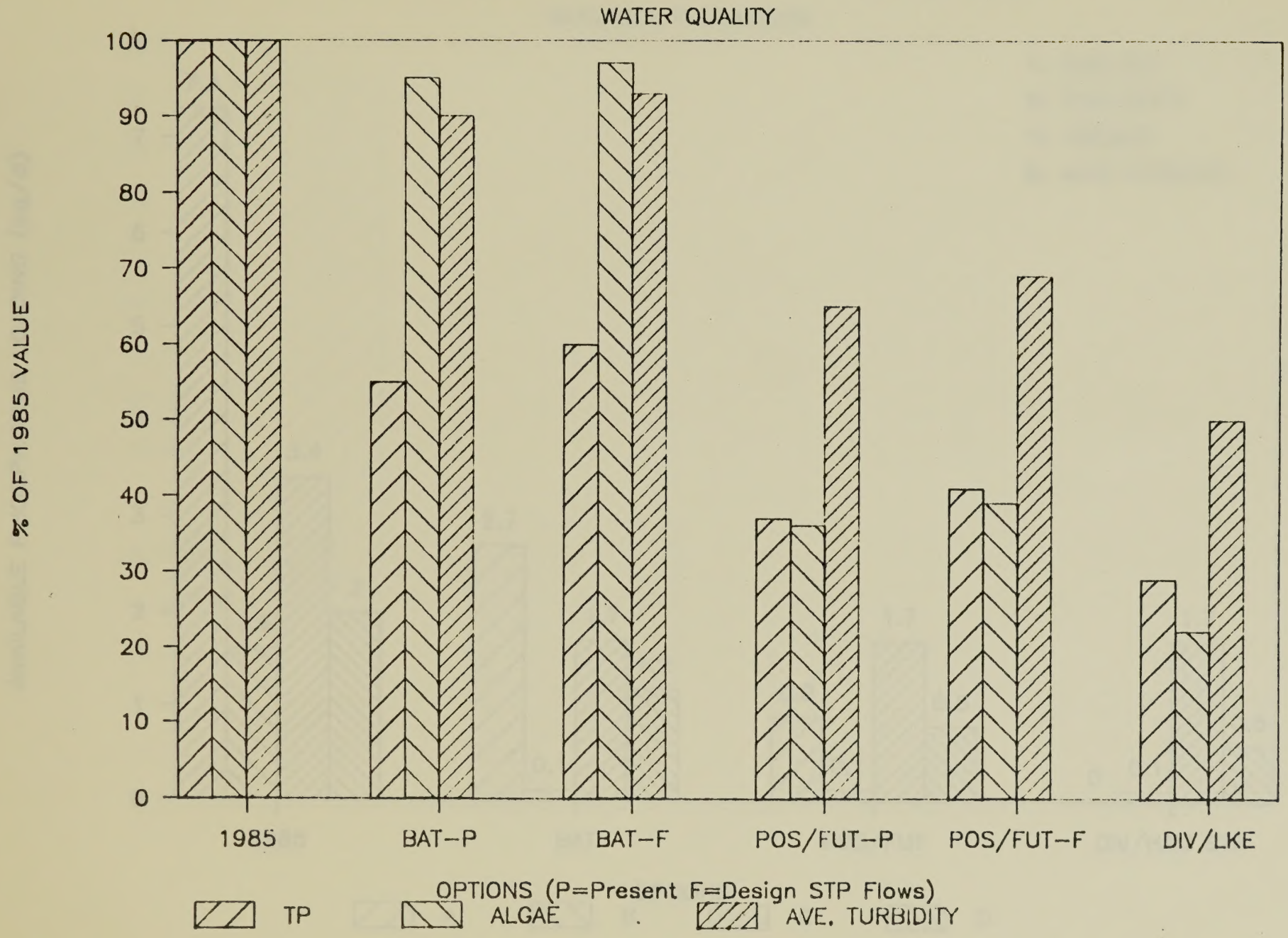


FIGURE 5: HAMILTON HARBOUR



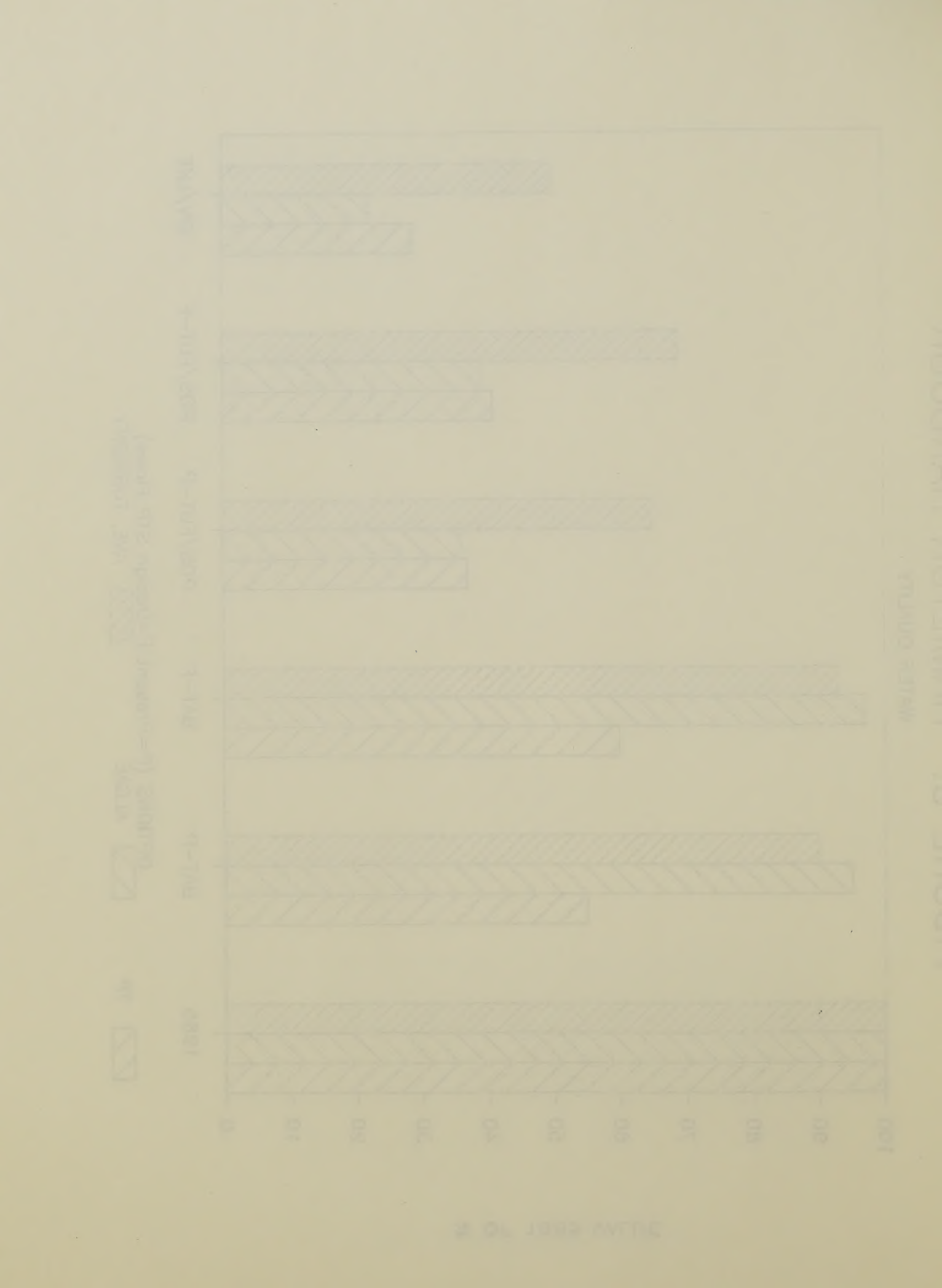


FIGURE 6: COOTES PARADISE

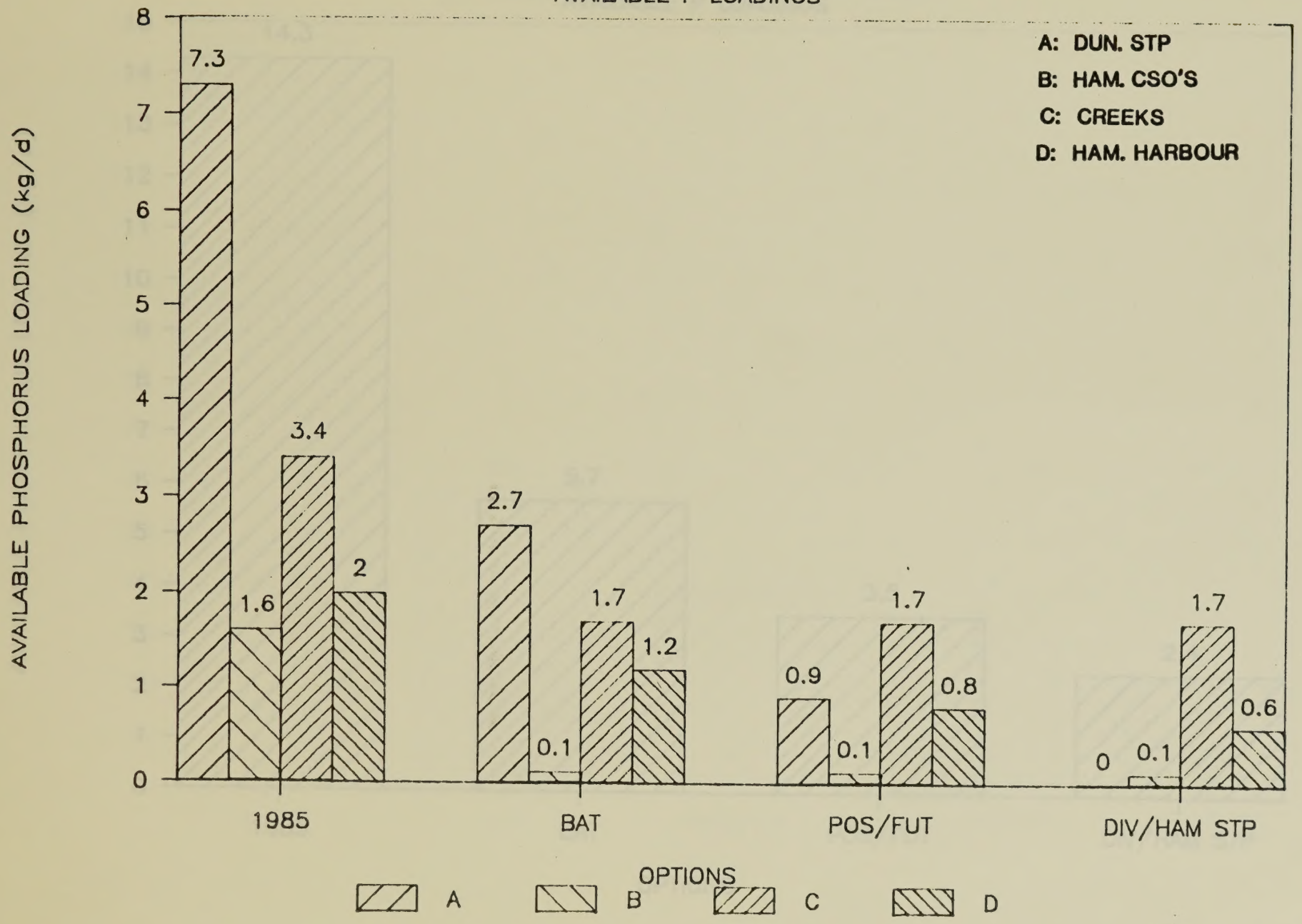


FIGURE 7: COOTES PARADISE

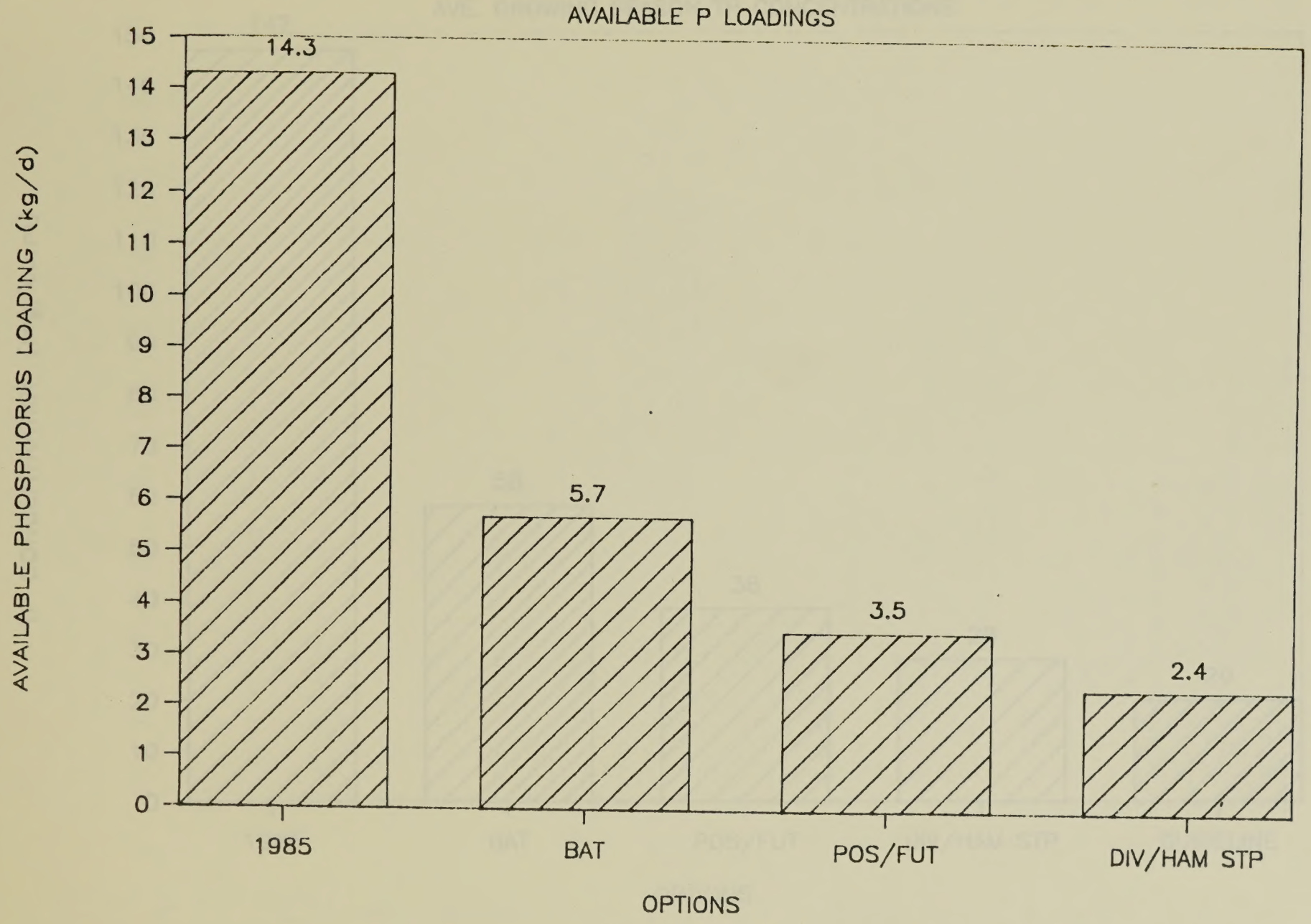


FIGURE 8: COOTES PARADISE

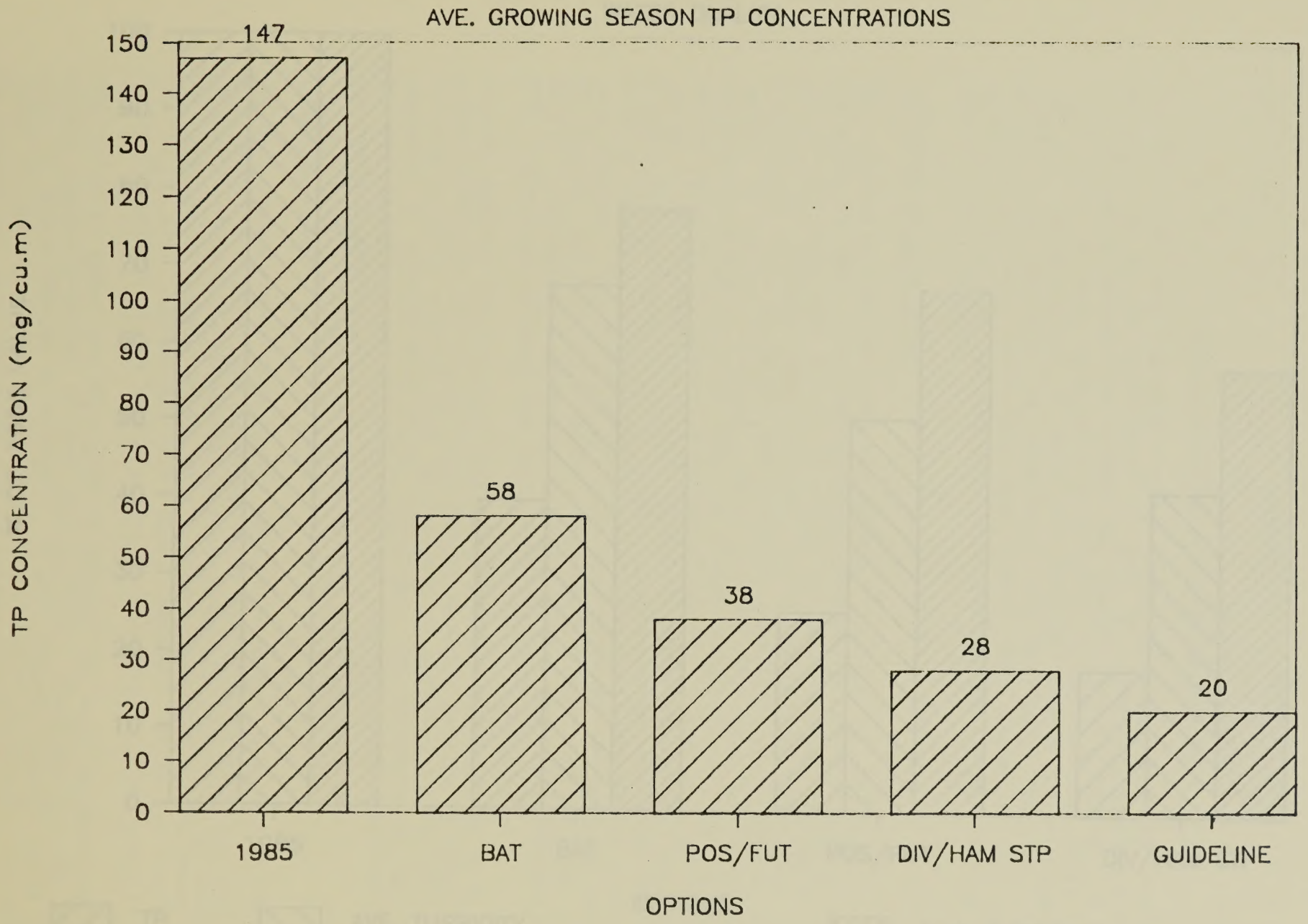
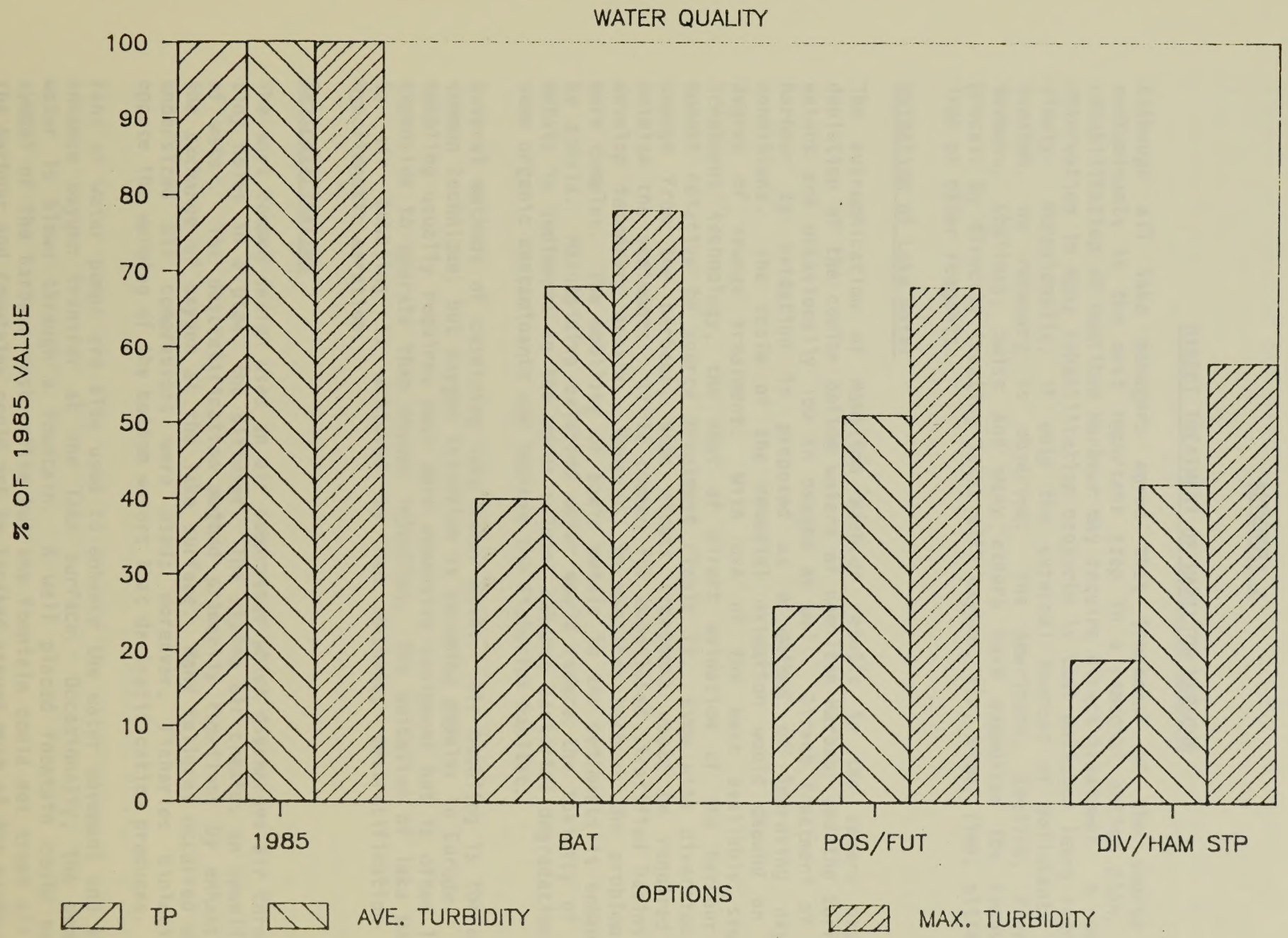
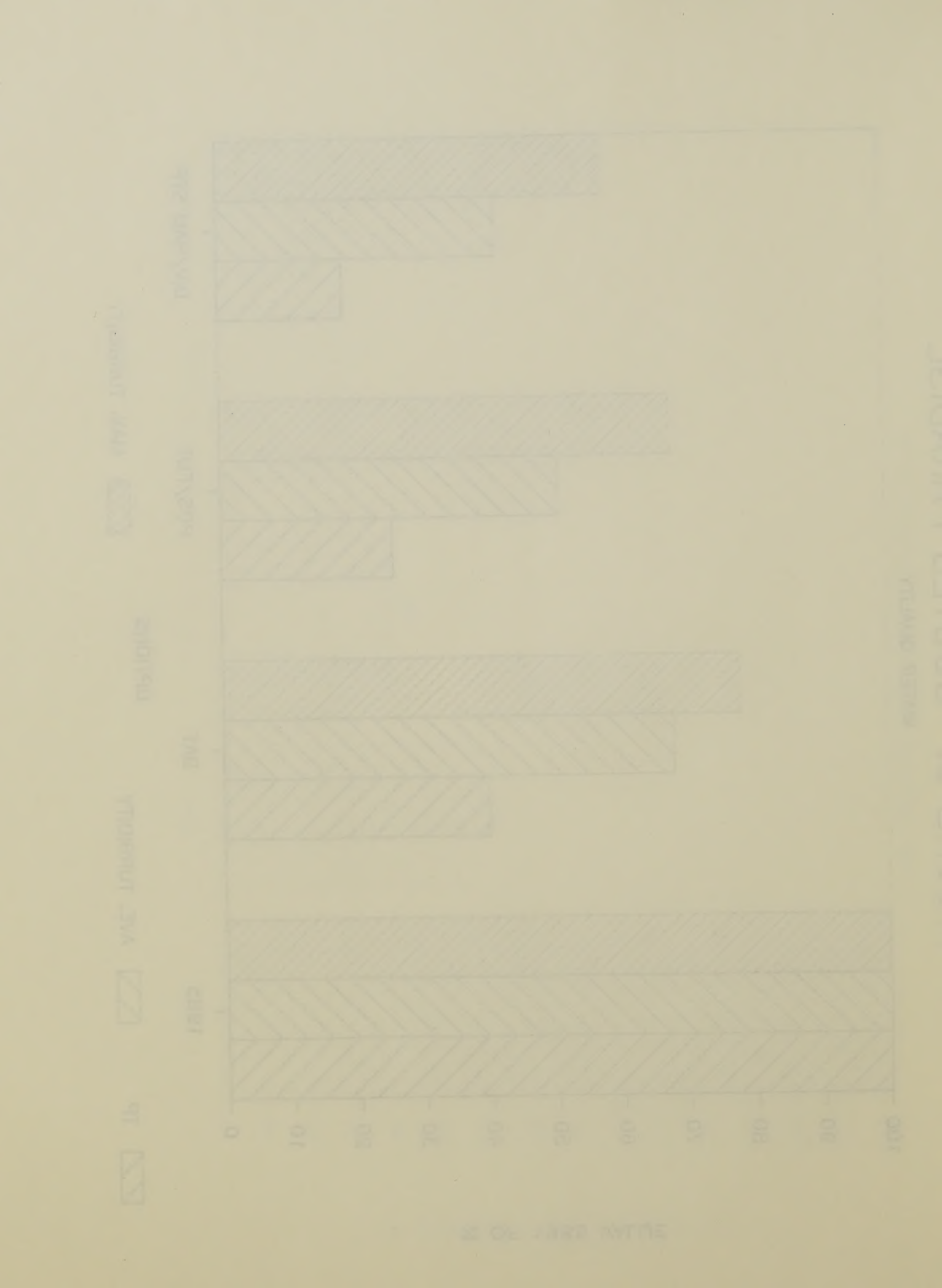


FIGURE 9: COOTES PARADISE





APPENDIX 2

DIRECT TREATMENT OF HAMILTON HARBOUR

Although all lake managers agree that treatment of the source of contaminants is the most important step in a remedial action plan, the rehabilitation of Hamilton Harbour may require direct treatment. A common observation in many rehabilitation projects is that polluted lakes recover slowly. Occasionally, if only the external sources of pollutants are treated, no recovery is observed. The Americans, English, French, Germans, Italians, Swiss and many others have expedited the recovery process by directly treating lakes with oxygen, air, alum, lime, nitrate, iron or other reagents.

Oxidation of Lake Water

The eutrophication of Hamilton Harbour results in the severe oxygen depletion of the cooler bottom waters of Hamilton Harbour and the surface waters are occasionally low in oxygen as well. Direct treatment of the harbour by oxidation is proposed as a method of improving oxygen conditions. The scale of the remedial oxidation would depend on the degree of sewage treatment. With use of the best available sewage treatment technology, the cost of direct oxidation of the harbour is modest relative to source treatment (Table 1). Even with diversion of sewage from the harbour, some direct treatment would be required to oxidize the sediments. It is common for unpolluted stratified basins to develop temporary anoxia. However, in Hamilton Harbour the problem is more complex. The mobility of toxic metals in the sediments is enhanced by anoxia. Maintaining oxidized water would reduce the toxicity of the metals in sediments to the water column, enhance bacterial degradation of some organic contaminants and improve the fisheries habitat.

Several methods of oxidizing lake water exist. Air bubbling is the most common technique, but oxygen injection is becoming popular in Europe. Air bubbling usually requires much more expensive equipment but is often less expensive to operate than oxygen injection. The oxidation of lake water by air bubbling is achieved by two methods, destratification or hypolimnetic aeration.

Destratification

The most common design uses an air compressor which discharges air through tiny holes in a pipe, the diffuser. The rising air creates an upwelling of water. The destratification method primarily functions by enhancing the exchange of oxygen at the lake surface. Many failures occurred when undersized air compressors were used; moreover, fisheries biologists oppose the warming of the bottom waters that destratification produces.

Fans or water pumps are also used to enhance the water movement and thus enhance oxygen transfer at the lake surface. Occasionally, the pumped water is blown through a fountain. A well placed fountain could be a symbol of the harbour restoration but one fountain could not treat all of the harbour and fountains could not be located around much of the harbour.

Another variation of destratification uses connected twin shafts that are drilled into the lake bottom. Air is then co-injected with pumped water down one shaft. The oxygen dissolves quickly at the great hydrostatic pressure at the bottom of the shaft, the air-water mixture passes to the other tube, and the rising plume of nitrogen that doesn't dissolve then acts as an air-lift pump.

Hypolimnetic Aeration

The other major type of air bubbling is hypolimnetic aeration. In these systems the water column is not mixed and the process oxidizes only the bottom of the lake. The advantage of hypolimnetic aeration is that the nutrient-rich bottom water is not mixed into the surface of the lake; thus, algal growth is not enhanced. Hypolimnetic aeration also enables the bottom water to remain cool; destratification warms the sediments and bottom water. Cooler sediments consume less oxygen and fish prefer a cool oxidized hypolimnion.

The most commonly used hypolimnetic system is the Bernhardt design. Air is injected into the bottom of a large pipe where is oxidizes the water as it rises to a degassing box. The oxidized water flows down a pipe back to the hypolimnion. This system has worked well in Germany and the design is simple and could easily be built locally. In Hamilton Harbour, the degassing box of a Bernhardt system would be a barrier to navigation and the box would have to be protected or removed in winter.

Atlas-Copeco has an hypolimnetic aeration design that is less restricting to navigation than the Bernhardt design. Air is pumped into an underwater mixing chamber. Under pressure the oxygen dissolves quickly. The residual nitrogen is vented to the surface via a small pipe that could be removed for the winter. The Atlas-Copeco system appears to be the least expensive hypolimnetic aeration system; moreover, it is the only hypolimnetic system that is commercially available that has been used at several sites. In Hamilton Harbour, this system could only be used on the Burlington shore because the units would interfere with shipping. The Harbour Commission would consider implementing a no anchorage area for aeration. The biggest local concern might be noise from the air compressors on the shore of a residential neighbourhood.

Locker International also has hypolimnetic aeration system. This system uses a water pump and a venturi to inject air. The Locker system is considerably more expensive than the Atlas-Copeco system, but a water pump is much quieter, easier, and less expensive to operate than an air compressor. The Locker system can be built on shore and this configuration would not disrupt shipping. Like all hypolimnetic systems, the Locker system has not been built on the scale that would be needed for the harbour.

The current oxygen demand in the hypolimnion of Hamilton Harbour is about three times larger than the largest hypolimnetic air bubbling system (10 tonnes oxygen demand per day, Bernhardt design, in West Germany). This scale is the approximate magnitude required to oxidize the harbour if advanced sewage treatment is implemented.

Oxygen Injection

Although several oxygen injection techniques exist, only two seem appropriate for Hamilton Harbour; diffusers, or a deep-shaft. The management options are quite different from air bubbling, the capital costs for diffusers are minor and oxygen is utilized only when it is needed. Oxygen is cheapest near industrial centers; thus, oxygen injection should be evaluated for the harbour.

The least expensive type of oxygen injection is done with diffusers. The type of diffuser varys from fritted stainless steel to small holes in hose. The Swiss are currently treating three lakes with pure oxygen injection through stainless steel diffusers. The largest treatment uses five tonnes of oxygen per day. Enough oxygen dissolves in the hypolimnion that the residual bubbles do not mix the water column. The lakes were oxidized, and eutrophication was reduced. In a reservoir on the Savannah River (USA), the injection of 100 tonnes of oxygen a day with ceramic diffusers was effective; destratification did not occur. In Hamilton Harbour, NWRI used simple porous plastic hose in a trial near the Lax property. A localized oxidation of the harbour was observed. Sediment resuspension was not observed. Diffusers do not interfere with navigation, but anchors would damage the diffusers.

Little information is available on other large projects, the oxygen treatment of Hong Kong Harbour or the Pearl River in Washington State. Larger projects have been implemented in sewage treatment systems (Detroit 380 tonnes o_2/d; New Jersey 500 tonnes O_2/d).

Some of the systems that are designed to use air have been used to inject oxygen. The Atlas-Copeco system has been used successfully in West Germany for oxygen injection. The deep-shaft method could be used for oxygen injection. This system has potential in Hamilton Harbour in that minimal interference with shipping would occur. Perhaps this system could be coupled to an industrial oxygen pipeline would reduce the operating costs considerably.

Numbers of Years That Direct Treatment is Required

In some places such as the Thames River, direct treatment with pure oxygen is only needed occasionally to prevent fish kills. If the sewage treatment in Hamilton Harbour is improved, Hamilton Harbour could become like the Thames River; treatment would be required only during certain events, such as a storm-sewer overflow. In some lakes such as Lake Ghirla in Italy, direct treatment with oxygen was only needed for one year.

Chemical Treatment of Hamilton Harbour

Iron Additions

In Hamilton, the local availability of iron could make the use of this chemical cost-effective. The West Germans, Dutch, and Irish have added iron to lakes to improve the precipitation of phosphorus. Hamilton Harbour has relatively high iron concentrations; thus, maintaining high

oxygen concentrations should precipitate iron. In laboratory incubations with Hamilton Harbour water and sediment, NWRI studies have found that when oxygen injection precipitated iorn, manganese, copper, lead, and zinc also precipitated. NWRI studies have shown that much of the iron in the harbour is present in complexes that are not reactive; thus, oxygen mediated precipitation of metals could be enhanced if more reactive iron compounds were added to the harbour. The lack of phosphorus release from the sediments of Hamilton Harbour is probably a reflection of the large historical iron loadings to the harbour. Application of iron to the harbour should be considered if toxic metals were not associated with iron.

Lime Application

Lime is another local product that is very useful in restoring lakes. The addition of lime to hardwater lakes has been done in B.C., Alberta, Poland and Wisconsin. In deep lakes with long water retention times, the effects are very striking; phosphorus and algae precipitate and the water column becomes clear. In the four NWRI treatments of western lakes, no fish were killed, and no adverse effects on zooplankton were observed. In Hamilton Harbour, the effects of lime treatment on the water column may be short-lived; however, if a storm does not result in a storm-sewer overflow, a treatment in June could clear the water column for the remainder of the summer. The precipitation of suspended solids by lime treatment should enhance light penetration for rooted plants. The possibility of enhanced phytoplankton growth can not be dismissed.

Effects of Lime Treatment on Lake Sediments

Lime treatment of sediments should produce more of a permanent treatment than can be achieved by lime in the water column. In NWRI laboratory treatments of Hamilton Harbour water and sediment, lime application resulted in the precipitation of lead, copper, iron and zinc. Although the NWRI study did not study cadmium, it is well known that cadmium is also bound tightly within the calcite lattice. Sealing the sediments with a chemical that prevents toxic metals from entering the water column would be an inexpensive alternative to dredging and disposal of contaminated sediments. Periodic treatment of the water column with lime for aesthetic reasons would eventually seal the sediments.

Nitrate Treatment

Another chemical treatment of sediments that warrants consideration is nitrate injection. Nitrate injection into Swedish lake sediments has resulted in oxidation of the sediment; phosphorus release and sediment oxygen demand were suppressed. In Hamilton, the high nitrogen discharge from the sewage treatment plants might oxidize the sediments if the ammonia was converted to nitrate. Oxidation of ammonia by the sewage treatment plant can be improved by increasing the mean residence time of the sewage sludge.

Physical Sealing of the Sediments

Physical barriers such as plastic to prevent sediment pollutants returning to the water column are inappropriate for a harbour. Sand

would probably sink through the surface organic layer; however, a clay layer might be effective. Although clay application could be considered, adjustments to natural clay inputs might achieve the same objective. For example, channelization of Cootes Paradise could result in the direct discharge of clay from Spencer's Creek into the harbour. Clay is more easily resuspended into the water column than lime; thus, turbidity could become a problem if clay was used to seal the sediments.

Table 1 Cost Estimates for In Situ Treatment of Hamilton Harbour

The three least expensive methods of treating the harbour directly are lime treatment, oxygen injection, and hypolimnetic aeration. The degree of sewage treatment influences the scale of direct treatment of the harbour; thus, three scales of treatment are considered; 1) no further improvements to sewage treatment plants (STP), 2) enhanced nitrification of sewage, and 3) enhanced nitrification and dual point treatment of sewage to remove nutrients, reduce the algal growth in the harbour, and in turn reduce algal decay by 50% (Vogt, MOE). This estimate uses Klapwijk and Snodgrass's 1984 model which estimates that 50% of the oxygen demand is from nitrification and 15% is from sediment demand. No cost estimates for source treatment are included here.

	No changes in STP		Nitrification Enhanced		Dual Point + Nitrification	
Treatment	Capital	O&M	Capital	O&M	Capital	O&M
Hypro Aeration	4-40m#	205k##	2.0-20m	103k	1-10m	52k
Oxygen Injection*	170k°°	360k**	85k	190k	85k	100k
Lime Treatment	0	100k*	0	100k	0	100k

Capital = equipment, O&M = operating expenses, k=$1,00, m=$1,000,000

Two quotations for 40 tonnes of oxygen a day to be injected using air bubling.

Estimate is for 128 days of operation.

° System would use simple diffusers to inject forty tonnes a day of oxygen at a 80% efficiency for 128 days in midsummer to midfall.

°° Costs include 15k for concrete pads, 30k for road improvement, 60k for hoses, and 40k for diffusers (k=thousand)

would probably sink through the surface organic layer; however, a clay layer might be effective. Although clay application could be considered substitutable to natural clay ponds might achieve the same objective, for example, consolidation of Castro Cove's muddy results in the first shipment of clay from Spencer's Creek into the harbour. Clay is more easily resuspended into the water column than peat; thus, turbidity could become a problem if clay was used to seal the sediments.

Table 1 Cost Estimates for In Situ Treatment of Hamilton Harbour

The three least expensive methods of treating the harbour directly are lime treatment, oxygen injection, and hypolimnetic aeration. The degree of sewage treatment influences the scale of direct treatment of the harbour; thus, three scales of treatment are considered; 1) no further improvements to sewage treatment plants (STP), 2) enhanced nitrification of sewage, and 3) enhanced nitrification and dual point treatment of sewage to remove nutrients, reduce the algal growth in the harbour, and in turn reduce algal decay by 30% (Vogt, 1980). This estimate uses Chapra and Dobbyrazz's 1984 model which estimates that 30% of the oxygen demand is from nitrification and 15% is from sediment demand. No cost estimates for source treatment are included here.

Treatment	No change in STP Capital	O&M	Nitrification Enhanced Capital	O&M	Dual Point + Nitrification Capital	O&M
Lime Addition	$4-10M	200$/d	2.5-20M	100$	1-10M	50$
Oxygen Injection*	170$**	300$**	80$	100$	20$	100$
Time Treatment	0	100$*	0	100$	0	100$

Capital = equipment, O&M = operating expenses, e.g. 1.00, $1,000,000

* Two quotations for 40 tonnes of oxygen a day to be injected using air bubbling.

Estimate is for 120 days of operation.

* System would use simple diffusers to inject forty tonnes a day of oxygen at a 80% efficiency for 120 days in midsummer to atleast.

** Costs include 15% for concrete pads, 30% for road improvement, 40% for hoses, and 40% for diffusers (K=thousand)

** This price is a simple extrapolation of the small project in Hamilton Harbour in 1986. Costs are usually less in larger scale. Moreover, the operating costs of using a pipeline to deliver oxygen would be much less than using trucks, but the capital cost of a pipeline and associated engineering are unavailable. The estimate assumes that destratification would not be broken and that the oxygen consumption would be 1 mg L^{-1} d^{-1}. A more modest oxygen requirement of 29 tonnes of oxygen per day could be derived by using estimates to current rates of hypolimnetic oxygen consumption; however, the higher rate of 40 tonnes per day would ensure that the sediments were oxidized.

* This estimate includes two treatments of 400 tonnes each. It assumes a best available price of $60 a tonne for lime and a contract (quotation received) of 40k to distribute the lime. This is twice the amount of treatment used in successful laboratory experiments; however, the amount of treatment needed in the harbour is still uncertain.

Tentative plans are for NWRI to test diffusers in 1987 on a large scale.

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